Corrosion

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DETROIT

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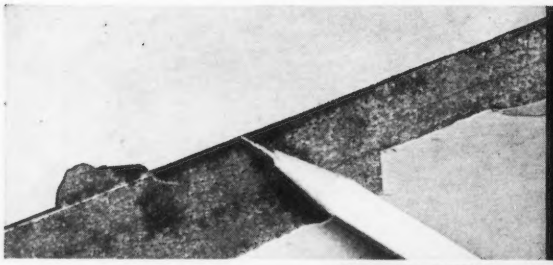
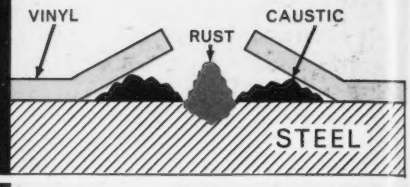
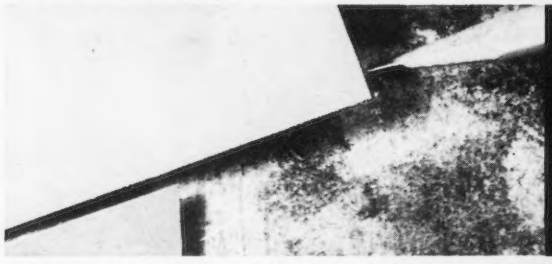
Here are tests you can duplicate

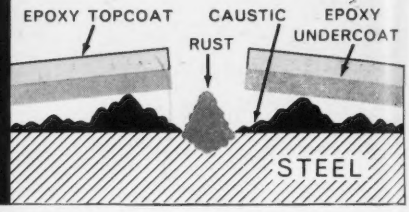


TEST 1—One coat of self-priming vinyl. Coating breaks away (L) due to severe undercutting (R), exposing metal to progressive corrosion.

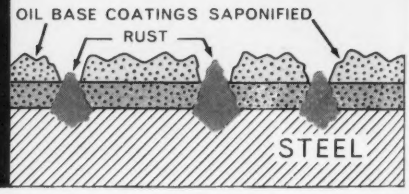


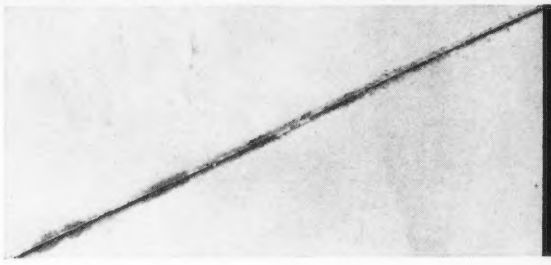


TEST 2—Epoxy primer, epoxy topcoat. Coating lifts off in single sheet (L) as adhesion fails (R), exposing entire surface to corrosion.

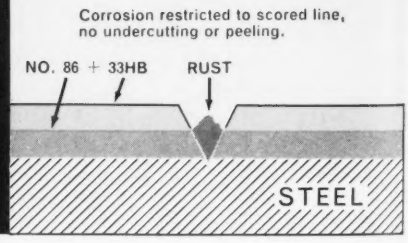


TEST 3—Oil primer, oil topcoat. Both coats fail completely (L) as underfilm caustic reacts on their oils to form soaps (R).





TEST 4—Amercoat's No. 86 inhibitive primer and No. 33HB vinyl topcoat. Corrosion restricted to scored line (L), no undercutting or peeling (R).



The purpose of these accelerated tests is to show what happens when various types of coatings are exposed to a typical corrosive environment. Four clean steel panels, free from mill scale and rust, were coated with different combinations of primers and topcoats. Each was scribed to bare metal and immersed in salt water in the presence of free oxygen, for two weeks.

As caustic deposits formed over cathodic areas of the steel in tests 1, 2 and 3, failure occurred in three ways. The vinyl, though not directly attacked, was undercut as caustic spread beneath the film and destroyed adhesion. The epoxy coating, known for critical adhesion to smooth metal, proved impervious to caustic attack. It was, however, lifted in its entirety as moisture spread beneath the surface. The entire oil paint film was quickly penetrated by the salt solution, creating widespread corrosion and caustic formation. The caustic then reacted with the oil to saponify the film.

In the fourth test the corrosion was limited to the score mark. Reason: Amercoat No. 86 Primer resists undercutting and adheres tenaciously, inhibiting electrolytic corrosive action.

The conclusions are clear. To provide long term protection in corrosive service, start with Amercoat No. 86 Primer, which provides a sound and lasting base for quality topcoats such as Amercoat No. 33HB.

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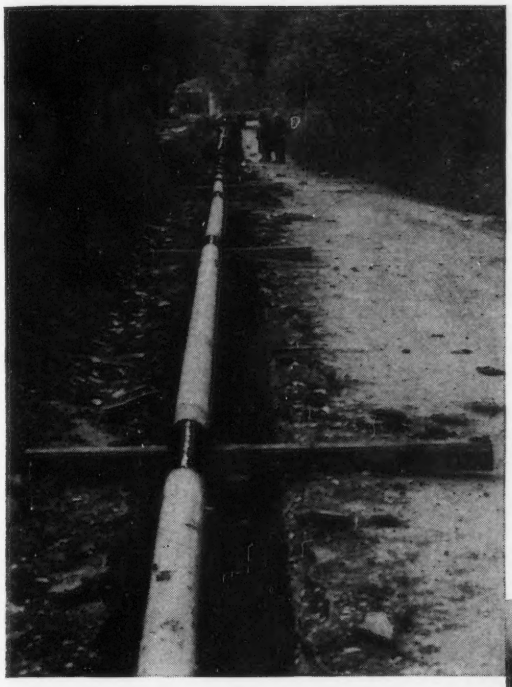

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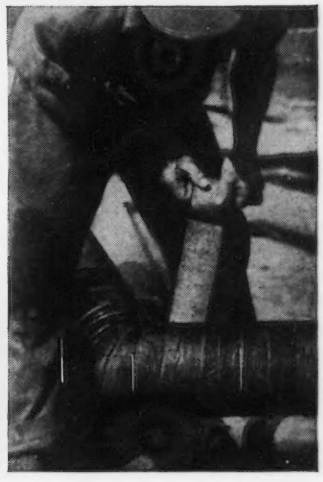

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Corrosion

devoted entirely to corrosion research and control

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THIS MONTH'S COVER—What happens to an offshore platform jacket after several years in the ocean is shown here. Although cathodically protected, the tidal zone area pictured did not benefit much. Heavy rust scale and damage is evident. Modern platforms designed on advice of corrosion engineers have simpler profiles and reduced area in the tidal zone so they can be protected better.

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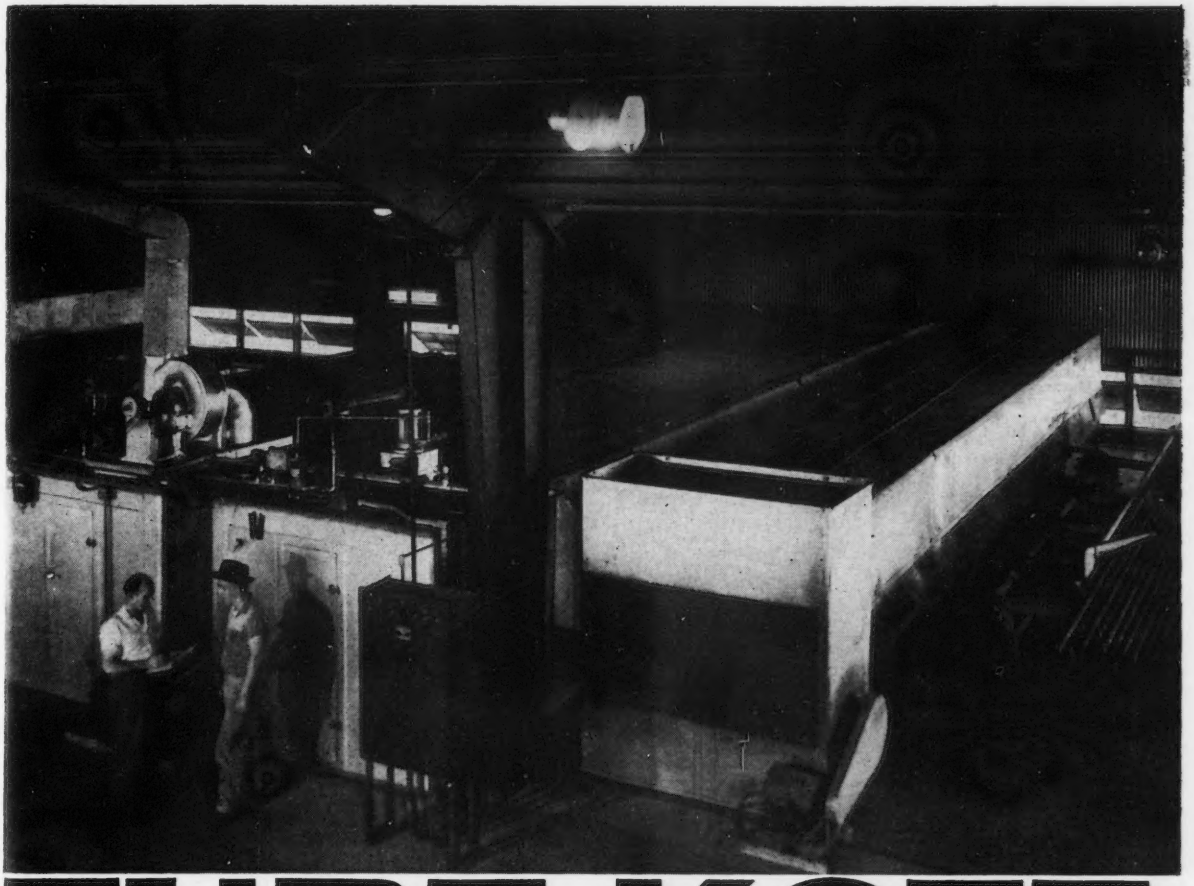

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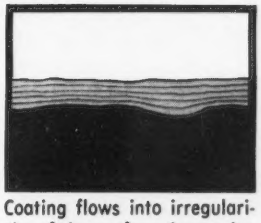

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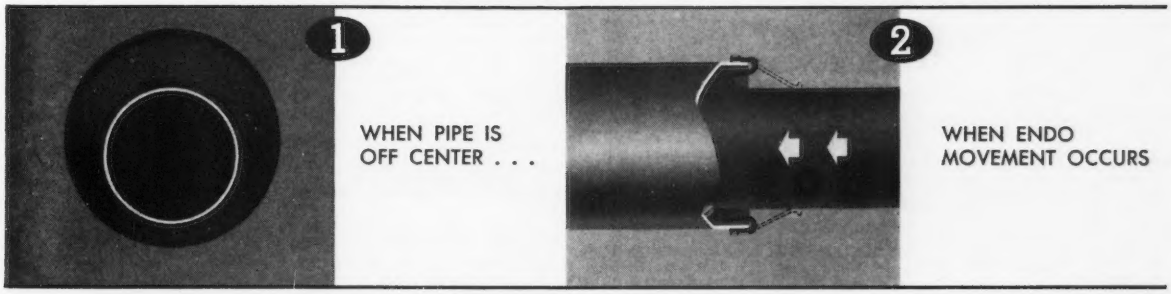

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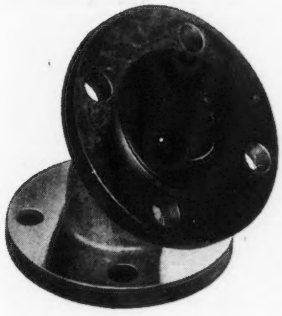

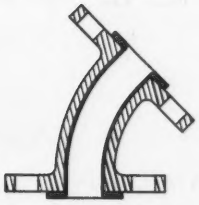

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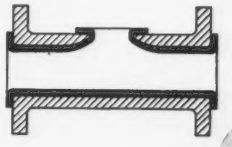

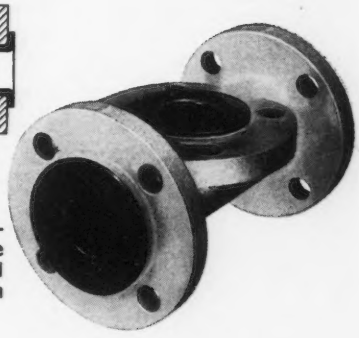

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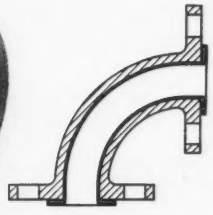

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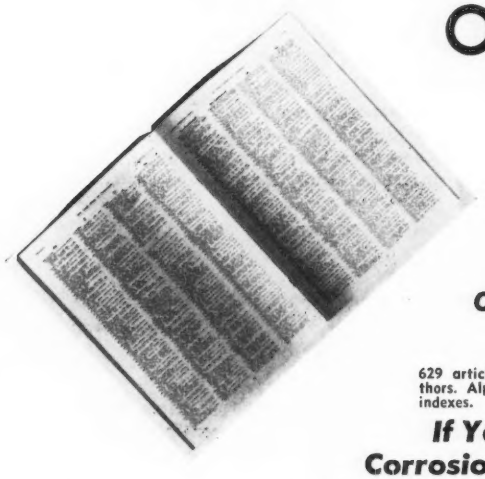

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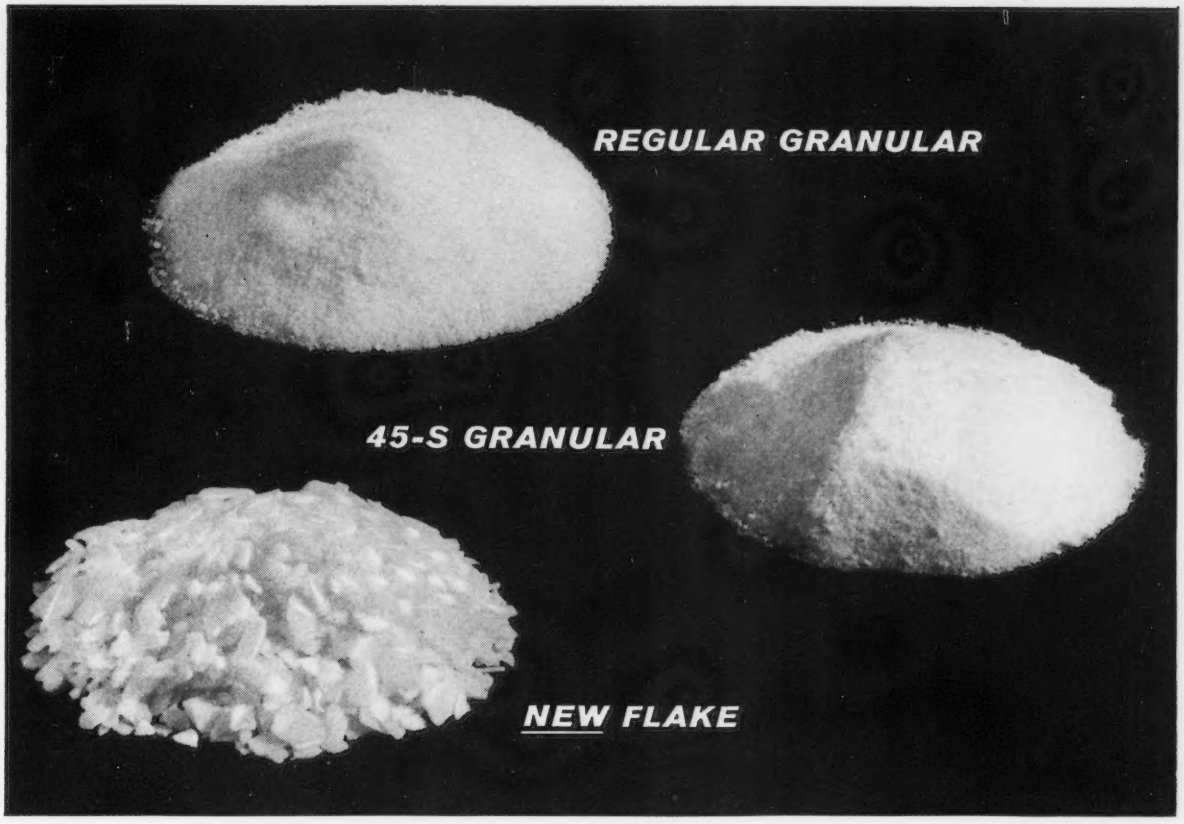

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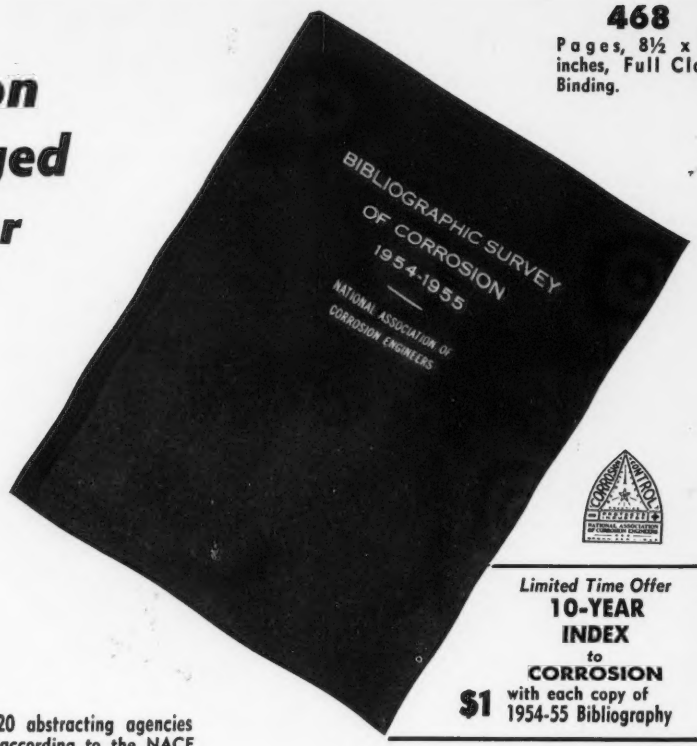

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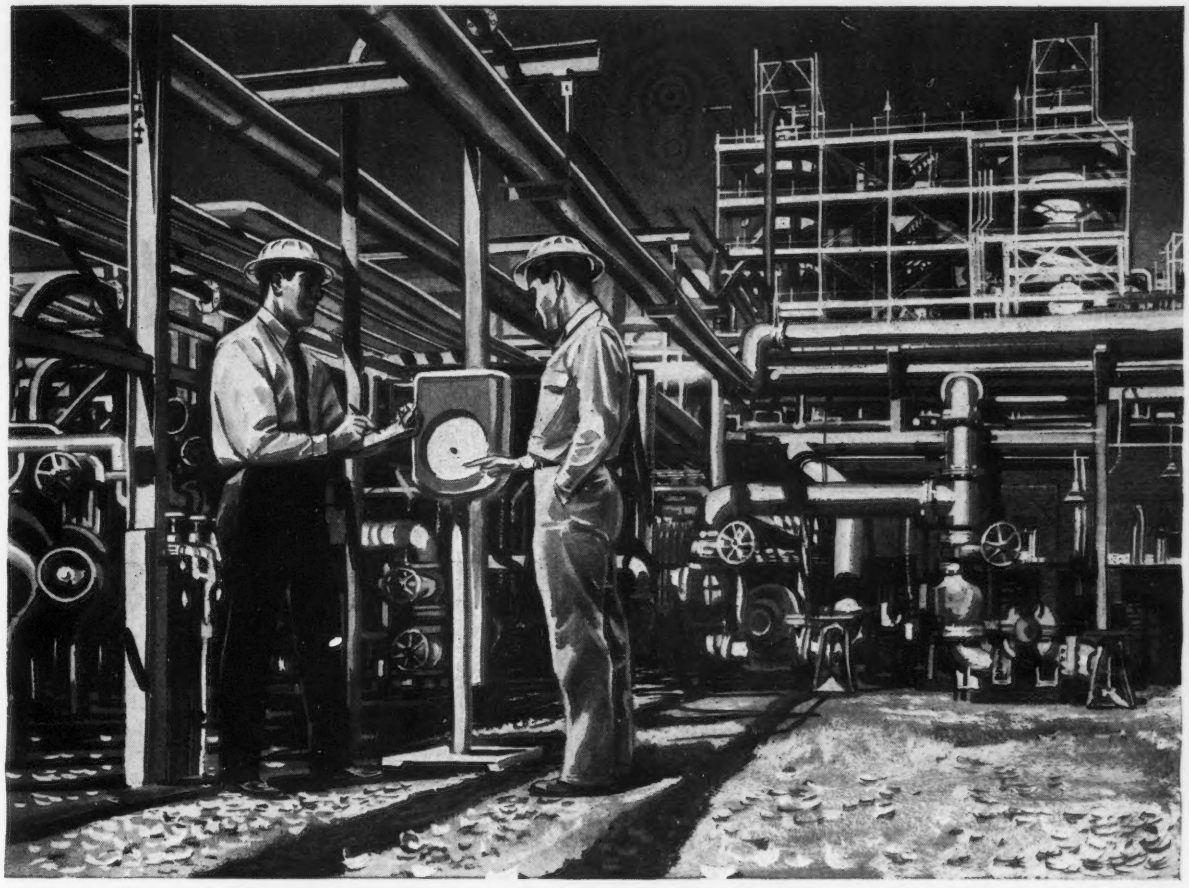

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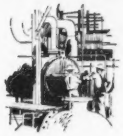

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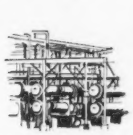

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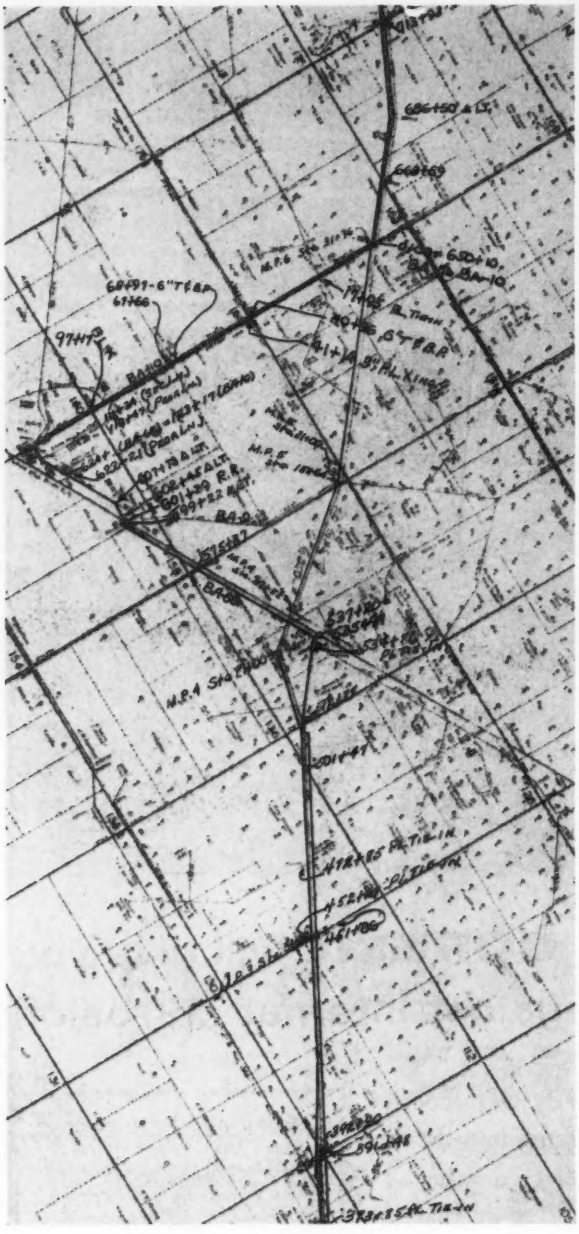

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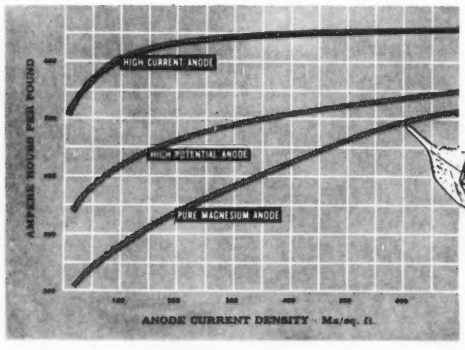

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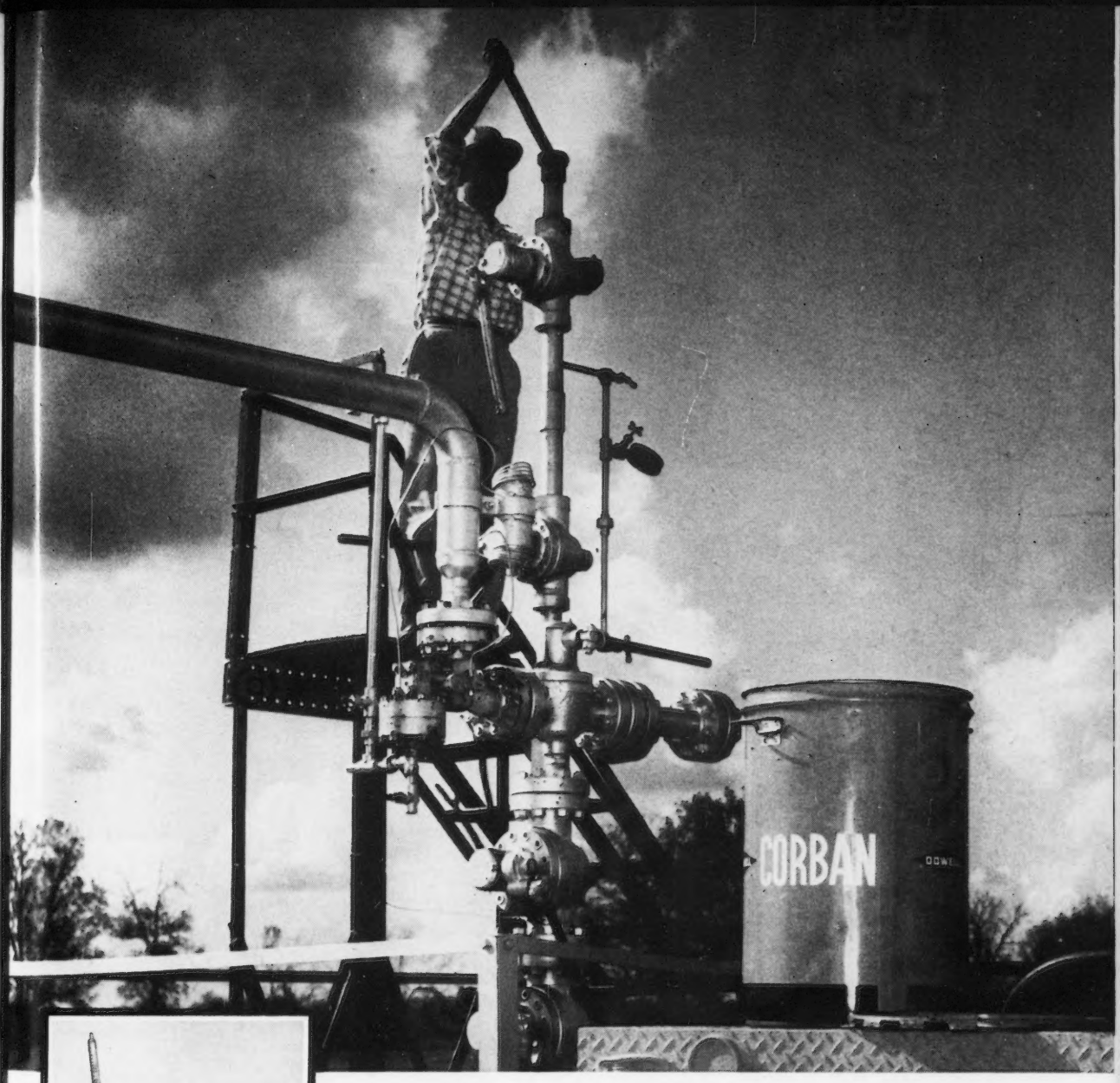

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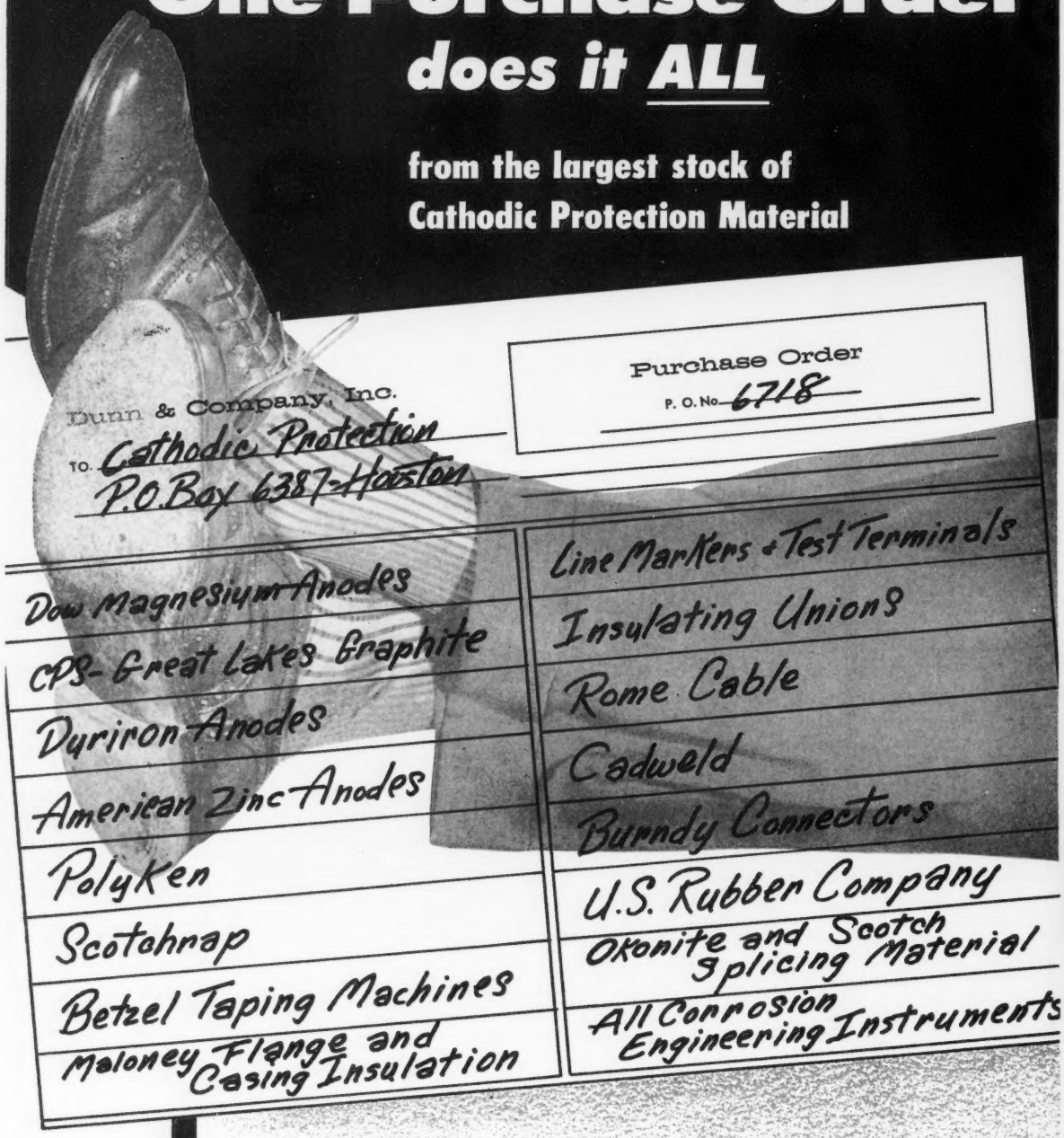

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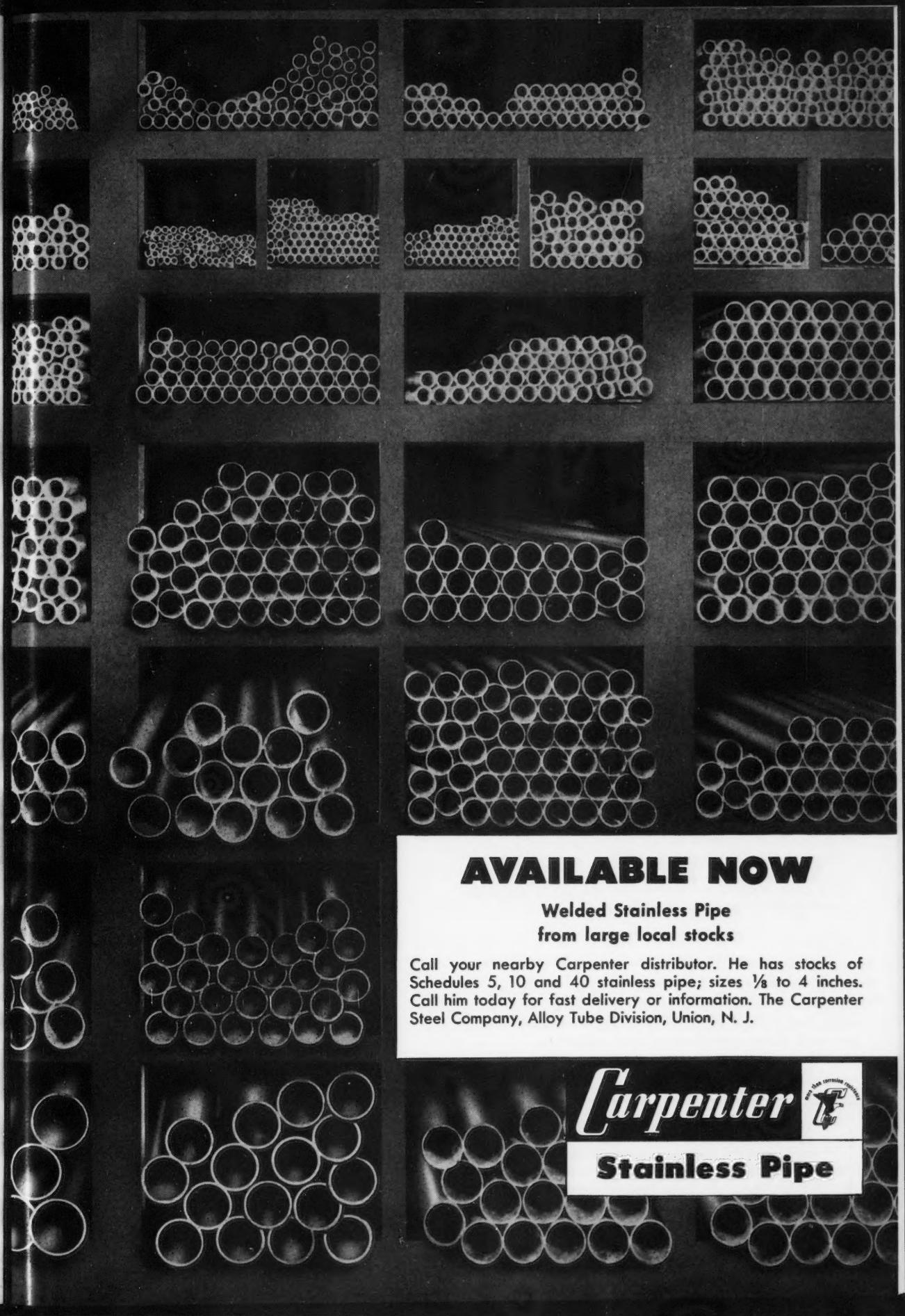

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(a) To promote the prevention of corrosion, thereby curtailing economic waste and conserving natural resources.

(b) To provide forums and media through which experiences with corrosion and its prevention may be reported, discussed and published for the common good.

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Corrosion

OFFICIAL MONTHLY PUBLICATION

National Association of Corrosion Engineers

An Association of Individuals and Organizations Concerned with Control of Corrosion

1061 M & M Building Houston 2, Texas

Vol. 14 June, 1958 No. 6

Topic of the Month

Erratic Performance of Type 1 Unplasticized Polyvinyl Chloride In 93 Percent Sulfuric Acid Pipelines

By H. E. ATKINSON, JR.* and T. F. DEGNAN*

Introduction

EXPERIENCE WITH Type 1 unplasticized polyvinyl chloride piping systems handling battery grade 93 percent sulfuric acid has shown this material to give excellent service if properly compounded and extruded. Polyvinyl chloride is potentially superior to lead or phenolic-lined steel since there is no possibility of metallic contamination.

The literature indicates that Type 1 unplasticized polyvinyl chloride is suitable for handling 93 percent sulfuric acid at ambient temperatures. However, failures have shown that much of the Type 1 PVC pipe is unsuitable for this service as manufactured today. An extension to a PVC line operating successfully for more than two years failed after seven months' service. Failure occurred by permeation and embrittlement. Failed pipe exhibited profuse "sweating" while the external surfaces of the original section remained dry. Replacement sections obtained from a second and then a third manufacturer failed in like manner. The original section is still in service after more than four years' use.

* Engineering Service Division, E. I. du Pont de Nemours and Company (Inc.), Wilmington, Delaware.

Test Program

A test program was undertaken to evaluate Type 1 PVC pipe for this service. The following test procedure was developed:

1. Rings ½ inch long were cut from 2-inch Schedule 80 pipe.

2. Sample was weighed in grams to two decimal places.

3. Sample was exposed in 93 percent (66 degrees Be) sulfuric acid at 55 C for 14 days. Sample was allowed to float freely.

4. Sample was removed, washed thoroughly in tap water, dried with air blast at room temperature, and weighed immediately.

5. Percent change in weight was calculated.

6. After two hours, sample was examined for sweating.

7. If color had changed from original, depth of color penetration was determined.

8. Ring was crushed in vise having smooth, flat jaws of length at least equal to length of crushed ring. Vise was closed at a slow uniform rate until opposite sides touched in approximately one minute. It was not necessary to establish line contact for full length of faces. It was essential for tests to be conducted at ambient temperature (70-80 F).

Data resulting from testing pipe from six vendors and from the original satis-

TABLE 1—Effect of 93 Percent Sulfuric Acid on Various Manufacturers' Type 1 PVC Pipe After 14 Days Exposure at 55 C

MATERIAL		Weight Change (%)	Pass Crush Test	Deflection At Break	Color	Depth of Acid Penetration	Degree of Sweating	Remarks
Original "A"	1	—3.7	Yes	....	Noticeable Darkening	Surface Effect Only	Dry	.....
	2	—6.2	Yes	....				.....
New Sample "A"	1	+1.26	Yes	....	Slight Darkening	Surface Effect Only	Dry	.....
	2	+1.05	Yes	....				.....
New Sample "B"	1	+17.6	Yes	....	Gray-Black	Complete	Considerable	.....
	2	+25.0	Yes	....				.....
New Sample "C"	1	+24.6	Broke	1¼"	Gray-Black	Complete	Considerable	.....
	2	+23.8	Yes	....				
New Sample "D"	1	+14.6	Yes	....	Jet Black	50%	Considerable	.....
	2	+16.7	Yes	....				
New Sample "E"	1	+18.9	Broke	0"	Jet Black	Complete	Considerable	Laminated—Exuding of Acid, Very Brittle.
	2	+21.2	Broke	1⅝"				
New Sample "F"	1	+11.8	Broke	0"	Jet Black	50%	Wet All Over	Laminated—Large Exuding of Acid
	2	+54.0	Broke	0"				
New Sample "A" in Water	1	+0.7	Yes	....	Natural Gray	Surface Effect Only	Dry	.....
	2	+0.6	Yes					.....

TABLE 2—Classification of Type 1 PVC Pipe Based on Results of 14 Day Test in 93 Percent Sulfuric Acid at 55 C

Property	Maximum Chemical Resistance	Standard Chemical Resistance
Weight Change —% (Max.)	±4	+25
Crush Test*	Yes	Yes
Color	Slight Darkening	Black
Penetration	Surface Effect Only	Complete
Sweating	None	Considerable

* Passing crush test requires that sample be crushed face-to-face without fracture or corner cracking. The presence of flow and strain lines does not constitute failure.

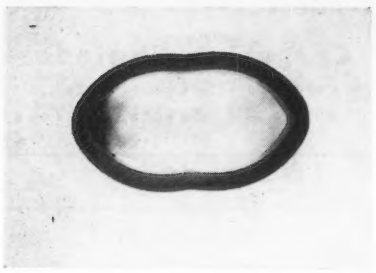

Figure 1—Sample that met maximum chemical resistance requirements.

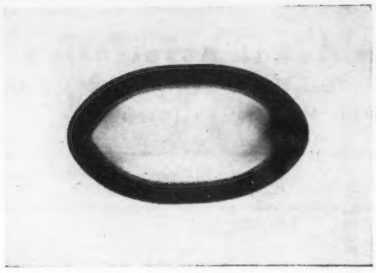

Figure 2—Sample that met standard chemical resistance requirements.

Figure 3—Samples that failed to qualify.

factory pipeline are recorded in Table 1. Photographs of a few rings are shown in Figures 1-3.

Conclusions

1. There are differences in the resistance of various vendor's Type 1 PVC to extremely corrosive sulfuric acid services. These differences apparently lie in the stabilizers, extrusion lubricants and extrusion techniques.

2. Only pipe meeting "maximum chemical resistance" requirements as shown in Table 2 may be used in 93 percent sulfuric acid.

Results

1. Du Pont Company purchase specifications have been revised to include two grades of chemically resistant Type 1 PVC pipe. Vendors must qualify on the basis of the test procedure.

2. In the development of ASTM material specifications for Type 1 PVC the differentiation between "maximum chemical resistance" and "standard chemical resistance" is being recognized. Round robin tests are planned to explore differences in resistance to chemicals other than sulfuric acid.

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Authors of technical papers on corrosion are invited to submit them for review without invitation to the Editor of Corrosion. Write for "Guide for the Preparation and Presentation of Papers" sent free on request to prospective authors.

Thin Metal Film Corrosion Indicators*

By DAVID ROLLER

Abstract

Tests were made to find a thin metal film which would act as both a visual and electrical corrosion indicator in connection with the packaging of hardware items. Selected for testing purposes were thin, continuous iron films which had been vacuum deposited on borosilicate glass and on Plexiglass 55 in thicknesses ranging from 100 to 2500 Angstroms. Measuring the electrical resistance per inch and computing the resistance per square of the films was a convenient, reasonably accurate method of comparing film thicknesses and determining the progress of corrosion. Early visual detection of corrosion products was not difficult due to change in film characteristics. However, changes in electrical resistance were not great until specimens were moderately corroded. A marked decrease in corrosion occurred when films were too thick or too thin and when Plexiglass 55 was used as a substrate rather than a borosilicate glass. Tests were conducted in atmospheres varying from 0 to 100 percent relative humidity.

The effects of different film compositions and characteristics, substrates, specimen preparation, and metal deposition techniques on corrosion rates are not completely understood. When the interrelationships of these factors and their influence on corrosion rate are more completely understood, it should be possible to make useful applications of thin metal films as corrosion indicators. 2.4.2

Introduction

THE STORING and stockpiling of packaged hardware items has increased greatly during the last ten years. This trend has been particularly noticeable with the military which preserves, packages, and stockpiles items ranging in size from extremely small bearings to entire aircraft.

Preservative techniques are of three basic types. Type 1 is the common oil or grease preservative, Type 2 involves the use of desiccants as silica gel, and Type 3 consists of just the physical protection afforded by the hardware item or package itself. Newer preservatives, primarily vapor corrosion inhibitors, commonly called VCI materials, have had only limited approval by the Armed Services. At present they are being used more extensively than in the past, but still are being used only with ferrous materials.

Inspection of packaged items in storage is usually accomplished at regular intervals. Normally a certain number of packages from a group are chosen at random and inspected as part of a statistically designed program. Inspection consists of opening the package, examining the contents, represerving the contents, and re-packaging. This is expensive and time consuming. As would be expected, manpower requirements for inspections and labor are high.

Present corrosion indicators used in packaging are in the form of chemical or electrical devices, which change their properties in the presence of a high humidity. The most common type of chemical indicator is cobalt chloride which changes its color at or around 30 percent relative humidity at room temperature. It is virtually unaffected by other corrosive environments such as acid fumes and apparently it can not be used with vapor corrosion inhibitors. Some other disadvantages of cobalt chloride are: (1) color transition is dependent on temperature, indicator concentration, and impurities, (2) on paper, the indicator tends to bleed through the barrier reducing its concentration, (3) in many applications the package must be opened to examine the indicator, (4) the indicator directly indicates only humidity and only indirectly the corrosiveness of the environment, and, (5) the color reaction of cobalt chloride is reversible and therefore the indicator does not integrate the corrosivity of the environment over periods of time.

Electrical indicators have been used but these require delicate sensing elements and considerable electrical equipment. In addition they are difficult to use in packages and indicate only the moisture content of the environment. Without expensive recording equipment, the indicator will not integrate its measurements over time. Another disadvantage is that electrical indicators can not be used with VCI materials.

★ Submitted for publication October 22, 1956. A paper presented at the Thirteenth Annual Conference, National Association of Corrosion Engineers, St. Louis, Missouri, March 11-15, 1957.

About the Author

DAVID ROLLER is Senior Project Engineer, Wright Air Development Center, Materials Laboratory, Wright-Patterson AFB, Ohio. He has a BS in chemistry from Massachusetts Institute of Technology, 1950 and has worked for Freeport Sulphur Company on problems associated with nickel-cobalt ores. His work with the Air Force has been principally in the corrosion field. Among other engineering organizations, he belongs to NACE.

In so far as can be determined, no corrosion indicator to date will: (1) actually determine directly the corrosity of the environment, (2) integrate the information over time, or (3) be more sensitive to corrosion than any hardware item when both are in the same environment without destructively changing the environment.

During investigations on allied subjects, it was conceived that the use of very thin metal films deposited on a suitable substrate might have excellent properties for use as corrosion indicators. Thin metal films of the order of 100 to 5000 Angstroms have a normal resistance of the order of 1.0 to 100 ohms per square(1) and when deposited have a characteristic appearance. In many cases, thin metal films change their visual appearance drastically during the process of corrosion. In addition, their electrical resistance increases several fold as the metal oxide is normally a much poorer electrical conductor than the base metal. It was felt that by using the proper materials, both film and substrate, that a visual and electrical corrosion indicator could be produced with many worthwhile properties. Thus, as the metal film corroded, surface characteristics of the film would change radically, which development would be apparent even to an untrained observer.

Test Program

Preparation of Sensing Elements

An appropriate sensing element, as determined in this investigation, consists of a thin metal film deposited as a coherent, uniform film over a suitable substrate. There are at least six different ways in which thin metal films can be adherently deposited on a substrate. These methods are[1]: (1) vacuum evaporation techniques, (2) sputtering techniques, (3) electroplating techniques, (4) chemical desposition, from either liquid or gaseous phases, (5) metal spraying and (6) frictional adhesion. Each method has its own characteristics but there are certain advantages to using vacuum deposition techniques to produce appropriate films.

Vacuum desposition or evaporation of metals within a high-vacuum chamber is now a well-known art. Pressures within a glass or metal bell may be readily reduced to 10^{-6} mm of mercury in 10 to 20 minutes by use of a series arrangement of a mechanical forepump and an oil-diffusion high vacuum pump. At pressures of this order, the mean free path of the gas molecules within the chamber becomes greater than the dimensions of the chamber. Small pellets of a chosen metal are suspended from a filament which is heated by means of an electric current. The globules of metal wet the filament and evaporate from the surface, depositing on the nearest cool surface which may be a chosen surface or the walls of the chamber. Evaporation of most metals is rather easily accomplished. The process is cheap, versatile, economical, and all equipment is readily available. Because of the nature of the deposition process, the metal film would be in an activated energy state and would be more prone to oxidize than the bulk metal.

The techniques used in this investigation to deposit thin iron films onto clean glass and plastic surfaces can be divided into two phases: surface substrate cleaning, and metal evaporation methods.

Substrate cleaning is important in ensuring a uniform, adherent, and continuous film. Glass slides were given a

(1)Ohms per square is the electrical resistance between two electrodes attached along the full length of two opposite sides of a square. The size of the square is immaterial. Use of the unit implies that the material being tested either is very thin or that current flow is confined entirely to the material's surface.

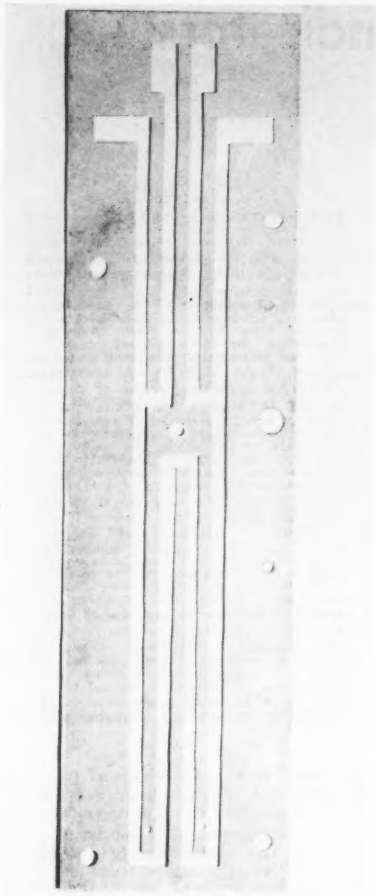

Figure 1—Aluminum mask used to produce electrical specimens. Mask is bolted to substrate.

TABLE 1—Comparison of Glass and Plastic Substrate Properties

Property	Glass	Plastics
Type	Borosilicate Glass	Polymethylmethacrylate Resin
Composition	70-80% SiO_2, 25-28% B_2O_3 1.0-1.7% Al_2O_3, Small amounts Na_2O, K_2O	Acrylate and Methacrylate Resins; no plasticizer is added.
Thermal Expansion in/in/°F	5×10^{-6}	5×10^{-5}
Light Transmission	Excellent	Excellent
Surface Resistivity ohms/square	10^{10}—10^{14}	10^{15}—10^{18}
Specific Gravity	2.2	1.2
Softening Point/°F	About 1500	150—255
Effect of Aging, Room Temp.	None	None
Manufacturer or Distributor	Central Scientific Co. (high grade non-corrosive microscope slides 3" x 1" about 1.0 min)	Rohm & Haas Co.

preliminary cleaning using two different methods. One method consisted of washing the glass in hot chromic acid, washing in distilled water, then drying by evaporation. The other method was to scrub the glass with ceric oxide (ceria) in denatured ethyl alcohol, rinse in alcohol, and wipe dry with surgical gauze. Plastic substrates were cleaned and washed in denatured ethyl alcohol and rinsed in distilled water. They were then agitated for five minutes in a solution of cold 5 percent sodium hydroxide, rinsed in distilled water, and agitated for three more minutes in a cold 15 percent nitric acid solution. They were finally rinsed with distilled water and dried. Thereafter, precautions were taken to reduce specimen handling to a minimum and then only with tweezers.

All slides were finally cleaned by exposure to a high glow discharge ionbombardment. This consisted of positioning the slides in the prepared bell jar, evacuating with a forepump to about 100 microns pressure, and exposing slides to a glow discharge of a thousand volts direct current for twenty to thirty minutes. This substantially removed any small quantities of absorbed moisture and residue.

Without further handling, the metal evaporating phase was started. This consisted of further evacuation of the bell jar using an oil diffusion pump to a vacuum of about 1.5×10^{-5} mm of mercury. An electric current was then passed through the previously positioned and weighed tungsten boat containing a known quantity of iron wire. A current of about 400 amperes and 10 volts AC heated the tungsten boat and contents to about 1550-1600 C. Normally one to three minutes was needed to vaporize the iron wire and coat the glass and plastic specimens which were arranged around the boat. The pressure usually rose during this time to about 10^{-4} mm mercury. Afterwards, dry air was bled into the system and the specimens carefully, but quickly, placed in a desiccator for storage until use.

Prior to testing, all specimens were visually and electrically examined to determine the uniformity and continuity of the thin metal film. A thorough visual and microscopic examination usually revealed any specimens which were coated poorly. Where gross discontinuities or large variations in metal film thickness were detected, the specimens were discarded. Most specimens did have very small pinholes particularly at the lower film thicknesses. These did not seem to affect the electrical resistance though it was noted that initial corrosion often centered around these points.

Measuring the electrical resistance of the metal film, in most cases, revealed any subtle non-uniformity in film thickness and was also a means of comparing films. Electrical measurements, using a sensitive ohm-meter, were made with the two electrical probes spaced exactly one inch apart. Actual spacing was accomplished by positioning the probes in a plastic spacer jig which could be moved at will. The ends of the probes were ground flat and polished until very smooth. With practice, a uniform pressure could be achieved to obtain reproducible resistance readings.

Multiple readings (five or more), were taken over the film area and averaged. Variations in readings over the film surface did not differ by more than the conceivable variations in method and rate of deposition. The effect of temperature change on the electrical-measurements and on the relative humidity was quite small in comparison with changes within the metal film since all tests were conducted in a constant temperature room. The averaged value of resistance so obtained was a qualitative measure of the resistance per square of the metal film. It is realized that the resistance values by this method are different from values which would have been obtained by the use of more exact techniques. However, the values obtained were consistent and did relate one specimen with another.

For end use application, gross changes of resistance would be desired. That is, the ratio of initial to final resistance would have to change by orders of 1.5 to 100 to be significant. The inaccuracies which occurred due to the techniques used were small compared to the changes desired; relative values of resistance rather than absolute values were measured.

Metal Film Specimens and Test Environments

Because it was expected that film changes during corrosion could be detected by both visual and electrical techniques, two types of specimens were designed. It was expected that visual specimens would be simply observed during a particular test. The electrical specimens would be used to measure the change in electrical resistance of the film without removing the specimen from the test environment. A specimen design developed recently by Dravnieks and Cataldi[2] was used which consisted of a long ribbon, the ends of which were split in half forming four leads. The leads, or tails, serve as "potential" and "current" connections.

Figure 1 is a photograph of the mask used to cover the plastic substrate and outline the specimen during metal deposition. The leads are the four rectangular openings at the top of the mask while the specimen starts at the junction of two leads and ends at the junction of the other two leads. The electrical ribbon specimens, from junction to junction, were approximately 2000 Angstroms thick, depending on the specimen, 0.125 inch wide and 17.375 inches long. The ribbon films had a calculated approximate resistance of about 2 to 10 ohms per square.

Two variables, film substrate and film thickness, were investigated in these tests. Purpose of the tests was to determine their influence on the corrosion rates of the metal film. Two widely different substrates, borosilicate glass as used in the manufacture of non-corrosive microscope slides and Plexiglass 55, a commercially available polymethacrylate resin, were used.

Table 1 gives a comparison of those substrate properties which might have affected film corrosion rates. Both substrates have excellent light transmission, high surface resistivities, good mechanical strength, and fairly small dimensional changes with moderate temperature increases, though having quite different chemical compositions.

Since Plexiglass 55 does not have a plasticizer present, the effect of this unknown factor was eliminated.

The metal used as a film material in this investigation was relatively pure iron. Fisher Scientific Company certified iron wire of at least 99.8 percent purity was used. An emission spectrographic analysis on several samples of the wire indicated the following composition: less than 0.1 percent silicon and 0.1 percent nickel; traces of magnesium, manganese, tin, aluminum, copper, chromium, calcium, molybdenum, and silver; balance iron.

After inspection, test specimens were placed in fixed static humidities ranging from zero to one hundred percent relative humidity. These were created by using large mouthed one gallon jars which could be sealed with metal screw caps. The jars, with a volume of 3.7 liters contained 0.5 liter of a sulfuric acid-water solution. By varying the acid concentrations, any humidity desired could be obtained. The procedure[3,4] is well described in the literature where it has been conclusively shown that sulfuric acid itself exerts no appreciable vapor pressure. In addition, when glycerine and water solutions were used to achieve suitable humid test environments, the same test results[5] were obtained.

Standard calculations for determining the proper volume and exposed surface area of solution compared to the volume of the container proved that a great excess of solution was present both as to volume and surface area. Density determinations before and after each test revealed no loss in water. Except for some preliminary work, all tests were made at a temperature of 25C ± 2 C. Because of the large exposed liquid area, equilibrium in the vapor phase probably was reached quickly. Theoretical heat transfer calculations indicated time intervals of less than an hour were needed to reach equilibrium. However, this did not appear to be such a critical factor due to the fact that similar equilibrium must be reached when hardware items are packaged.

Visual specimens were attached to wires by means of small alligator clamps. The wires passed through the lid of the container and supported the specimen. A rectangular slot was cut into the center of the metal lid through which passed the larger electrical specimen. Modeling clay was used to hold the specimen in place and to cover holes in the container lid to prevent loss of water.

To prevent contact between the clay and the metal film of the electrical specimens, a piece of moisture proof, high resistance tape was placed over the film at the point where the specimen passed through the lid as shown in Figure 2. When possible, specimens of widely different thicknesses, along with some duplicates, using both types of substrates, were placed in the same corrosive environment.

Test Results and Discussion

At least five specimens were tested in each environment, a static air atmosphere of either 0, 40, 60, 80, 90, or 100 percent relative humidity. Prior to exposure, the thin iron films were continuous, fairly uniform, shiny, mirror-like plates. After exposure to humid conditions and varying with time, corrosion occurred, and red dust formation and film breakdown was observed.

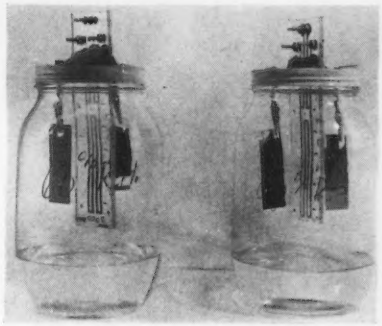

Figure 2—Visual and electrical test specimens in corrosive environment. Specimen at left is in an atmosphere having a relative humidity of 60 percent and sample at right is in an atmosphere having a relative humidity of 90 percent.

Normally, small to moderate corrosion was noted in about 15.5 hours at 100 percent relative humidity; 17.5 hours at 90 percent relative humidity; 18 hours at 80 percent relative humidity; about 45 hours at 60 percent relative humidity; and approximately 340 hours at 40 percent relative humidity. No corrosion was noted on specimens placed in a nominal 0 percent relative humidity or in a desiccator for periods up to 4 months respectively. Periods of time required for initial and moderate corrosion to occur were reproducible within 20 percent when duplicate specimens were used. Results obtained in this preliminary investigation were confirmed and duplicated closely in similar tests at Georgia Institute of Technology where an extensive research program on the corrosion rates of thin metal films is being conducted for the Air Force.[5]

Visually it was noted that under similar conditions the amount of corrosion where plastic was the substrate material was much less than where glass was used. Visual corrosion, the formation of rust, normally appeared as pits or as rust streaks. Corrosion products could be discerned easily either from the front looking at the film or from the back looking through the substrate. Many times corrosion started in small film imperfections or along the film edge; as corrosion continued, these corroded areas grew in size. Initial pitting, which was as small as 1/64 to 1/16 inch in diameter, could be discerned easily because of its reddish-brown rust color in contrast to the uncorroded shiny silver finish.

Figure 3 is a photograph of representative corroded and non-corroded specimens which have been subjected to a high static humidity. The specimen was subjected for approximately 30 hours to a static environment of 90 percent relative humidity at 25 C prior to being photographed. Note that the streaking and spots represent rusted areas which permit the transmission of light. The small pinhole or scratched areas on the uncorroded specimen which transmit light are film imperfections. These were caused by difficulties either in fabrication or in making preliminary electrical measurements.

Though corrosion could be readily determined visually, the electrical resistance of the film normally did not increase appreciably until corrosion was well advanced. This seemed to be due to the nature of the corrosive attack. Corrosion in the form of small pits or

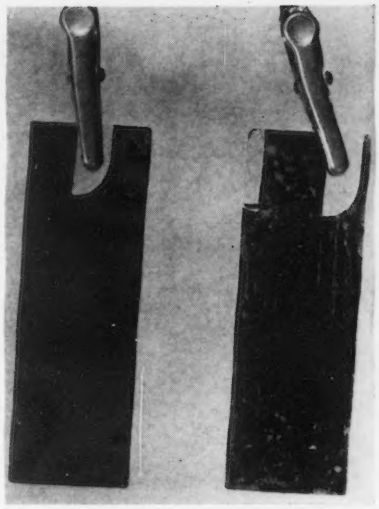

Figure 3—Appearance of specimens after test. Sample at left did not corrode while sample at right corroded.

short streaks did not affect the gross electrical resistance of the ⅛ inch wide ribbon film. However, if corrosion progressed to a moderate amount, resistances would increase progressively until quite large, almost infinite values, were measured. Since increases in electrical resistance were usually of a very small magnitude, film resistance during the various phases of corrosion are not tabulated. In most cases, the ratio of final to initial film resistance was usually between 1.0 and 1.2 when light corrosion was quite visible.

It is felt that techniques could be easily developed to determine accurately the change in resistance of thin metal films to be used as corrosion indicators. It is realized that if narrower films had been used in these tests, the change in resistance as the film corroded would have been greater. That is, a discrete pit or rust spots would have had a greater influence on the film's electrical resistance. Since these tests were more to determine the feasibility of using thin metal films as corrosion indicators and because visual techniques offered no difficulty, extended use of resistance measurements was not undertaken.

Microscopic examination of corroded areas revealed that the effect of corrosion toward the metal films varied. In certain cases, complete cracking of the film occurred, as if the film had shrunk or the substrate had been flexed. This was particularly noted in preliminary tests when specimens were subjected to high humidity and temperatures around 50 C. A certain tendency for the corrosion products to globulize and form little spheres also was noted. This has been observed by other investigators[6,7,8] and is thought to be due to the condition of the substrate and the method of preparation of the film. Essentially infinite resistance was found in all corroded areas. Figures 4 and 5 show microphotographs of iron corrosion products found on glass and plastic substrates.

Differences in the rate and amount of corrosion on specimens in the same environment appeared due to two main causes: film thickness and film substrate. The possible influence of cleaning and deposition techniques was not in-

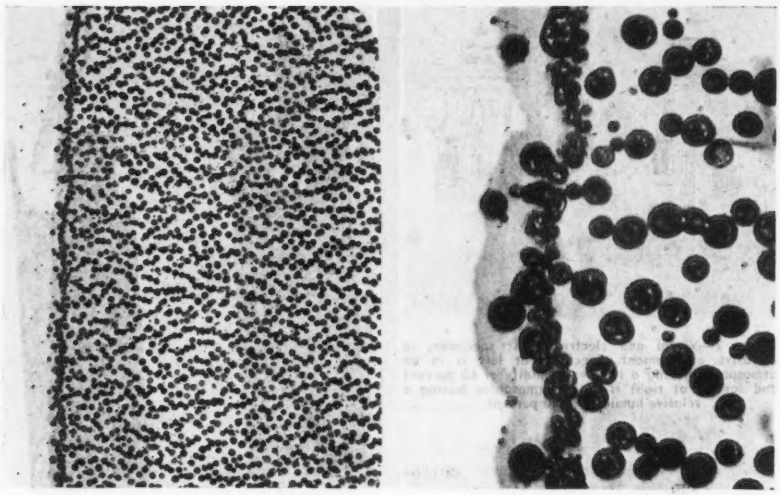

Figure 4—Iron film corrosion on a glass substrate in 80 percent relative humidity at 25 C for 20 hours. No etch or treatment was used. Photograph at left is shown at a magnification of 100X and that on the right at 500X.

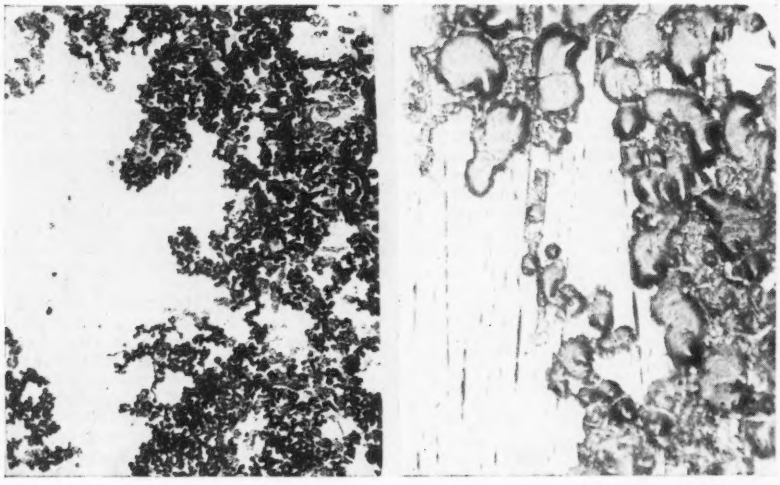

Figure 5—Iron film corrosion on a plastic substrate in 80 percent relative humidity at 25 C for 20 hours. No etch or treatment was used. Photograph at left is shown at a magnification of 100X and that on the right at 500X.

TABLE 2—Summary of Test Reports

Percent Relative Humidity	Type Substrate	Nominal Thickness Angstroms	Initial Resistance Ohms/Sq.	Initial Corrosion Nominal Hrs.	Moderate Corrosion Nominal Hrs.
0	Glass or Plastic	150–1600	8–95	over 2200	No corrosion in desiccator in 4 months
40	Glass	300–900	18–50	324–600	840
40	Plastic	200–450	25–85	550–2400	
60	Glass	450–1100	11–40	41–60	700
60	Plastic	300–2000	7–50	48–60	700–1200
80	Glass	300–500	30–50	18	32
80	Plastic	2000	8	18	40
90	Glass	400–1200	12–45	18–22	28
90	Plastic	300–1100	10–50	22–31.5	72–140
100	Glass	400–1800	7–40	15	29.5
100	Plastic	300–500	30–50	15	29.5

vestigated but might also have had considerable effect.

As a substrate material, Plexiglass 55 appeared to decrease the rate of corrosion of deposited iron films when compared to nominally equivalent films deposited on borosilicate glass. Films having thicknesses between a nominal 500 to 1000 Angstroms and electrical resistances between 15 and 30 ohms per square, corroded faster than films much more thick or thin. Tabulated results of tests made in this preliminary investigation are shown in Table 2.

These effects might be attributed to two main factors: differences in the chemical and/or physical characteristics of the substrates, and the nature of the films deposited on them. The presence of silica and boron as acidic oxides might, in the presence of moisture, cause more rapid corrosion. The effect of different polarities and surface tensions of the two substrate materials also might affect the rate of corrosion on the iron films. Variation in intermolecular attractions and surface energies affecting changes in film orientation might explain the apparent changes in corrosion rate with film thickness. The effect of these interrelated factors on corrosion rates of thin iron films is not completely known at this time.

Further studies are being initiated by the Air Force to determine the effect of placing single, dual, and multi metal films in static humid environments. It is hoped that information gained can be used to determine the basic mechanisms of thin metal film corrosion as well as appropriate substrate materials to use in corrosion indicator hardware items.

Conclusions

A need exists for a sensitive, inexpensive, easily used, replaceable, and conveniently fabricated direct reading corrosion indicator and detector. This type of indicator could be readily used in packaging of hardware items, in determining corrosive environments, and in research and development.

Thin, continuous, adherent iron films have been vacuum deposited on borosilicate glass and on Plexiglass 55 in thicknesses ranging from a nominal 100 to 2500 Angstroms. Measuring the electrical resistance per inch and computing the resistance per square of the films was a convenient, reasonably accurate method of comparing film thicknesses and determining the progress of corrosion. Thin iron films of a nominal 500 to 1000 Angstroms thickness (15 to 30 ohms per square resistance) corroded quite rapidly in static relative humidities ranging from 40 to 100 percent. Early visual detection of corrosion products was not difficult due to change in film characteristics, primarily color. However, changes in electrical resistance were not great until the specimens were moderately corroded. A marked decrease in corrosion occurred when films were too thick or too thin and when Plexiglass 55 was used as a substrate rather than a borosilicate glass.

The effect of different film compositions and characteristics, substrates, specimen preparation, and metal deposition techniques on corrosion rates are not completely understood. It is necessary to understand more completely the interrelationships of these factors and their influence on corrosion rate before useful applications of thin metal films can be made.

It appears possible to develop a visual and/or electrical corrosion indicator which would incorporate a sensitive thin metal film as the sensing element. By varying the composition and thickness of the metal film, the substrate materials, and by using appropriate sensing element designs, either electrical or visual corrosion indicators of varying sensitivity can be readily developed.

Future Applications

From this preliminary investigation certain assumptions appeared reasonable to this laboratory. These are: (1) thin metal films are greatly affected by corrosive (humid) environments and these changes can be seen, in many

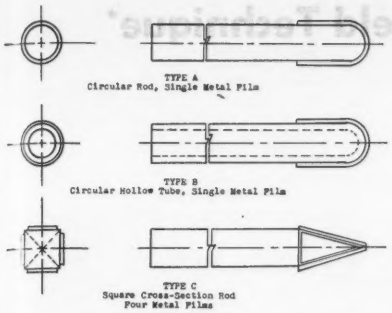

Figure 6—Three types of visual direct reading corrosion indicators.

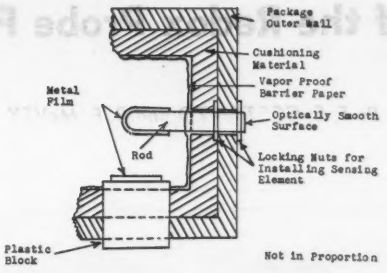

Figure 7—Container with visual corrosion indicators.

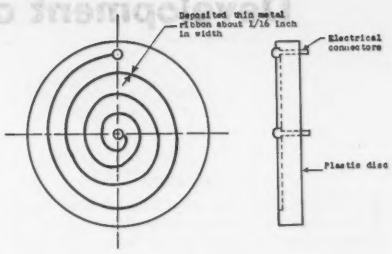

Figure 8—Disc type of electrical corrosion indicator sensing element.

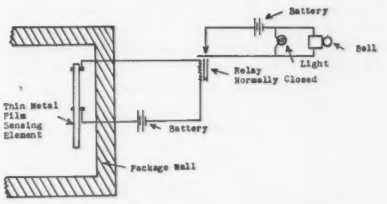

Figure 9—Electrical circuit with corrosion indicator in package. The corrosion indicator sensing element, detailed previously, is shown mounted in a package. A simple electrical circuit can be used to signal a corrosive environment.

cases, both visually and electrically, (2) even though little is known, it is presumed that metal films can be devised that will have various rates of corrosion in the same corrosive environment, and (3) thin metal films can economically be deposited on various substrates and can reasonably be expected to fulfill many of the qualifications for an excellent corrosion indicator sensing element.

These assumptions have led to a research program designed to develop various types of visual and/or electrical corrosion indicators which will use a thin metal film as the sensing element. Three types are currently being considered. The first is a "Scotch Tape" type corrosion test strip consisting of a pliable plastic tape. On one side of the plastic tape, a suitably uniform, thin, adherent metal film will be deposited. On the other side will be an adhesive material which will not be deleterious to the metal film if the two objects should come in contact. Provision for handling of the tape to prevent fingerprint contact and for dissemination of the tape will be taken into account.

Another approach will consist of depositing the film on solid and hollow glass and plastic rods having circular cross-sections. Using an otoscope (the doctor's device for visual examination of internal body areas) or similar instrument, observers can peer through one end of the rod and examine the other end where the film has been deposited. Thus the sensing element inside the light-tight package can be observed without opening the package.

A possible electrical indicator might consist of a thin plastic disc onto which the metal film is deposited as a very thin ribbon in the grooves or roots of a spiral channel on the substrate surface. In production, a hot spiral die or stamp is forced against the surface of the plastic disc forming a spiral groove. Two holes are drilled, to receive snap rivets or bolts, for connecting the electrical leads at the center and end of the spiral. The disc is then prepared for metal deposition. After being plated with the appropriate metal, the disc is then buffed to remove the metal on the surface leaving the very thin metal spiral in the groove. A simple electrical circuit can be devised which will rely on the change in electrical resistance of the protected thin metal spiral (which is between 1/16 inch and 1/32 inch wide) as the sensing element to actuate an alarm circuit. To be acceptable, all of these corrosion indicators should be inexpensively mass produced, sensitive to corrosion, able to withstand rough handling, and reliable. It is hoped that research will develop indicator sensing elements of various sensitivities by varying the type and thickness of the thin metal films. Figures 6, 7, 8, and 9 show several types of indicator sensing elements now under development and possible methods of using them in packages.

There is no theoretical reason why such a device could not be used with all methods of packaging an item. Certainly techniques and equipment appear to be available for cheaply mass producing such a corrosion indicator. Installation of these devices into the various types of packages does not appear to be insurmountable but is merely an engineering problem.

Acknowledgments

The author wishes to thank J. Teres of the Materials Laboratory for many of the original concepts concerning this project and for his technical advice and cooperation. Others who materially assisted the author were R. Hickmott of the Analysis and Measurements Section who prepared the specimens, and O. O. Srp, Supervisor of the Electrochemical and Corrosion Section of the Materials Laboratory.

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DISCUSSION

Questions by H. Phelps, U. S. Steel Research Laboratory, Monroeville, Pennsylvania:

What humidity level is considered safe for packaged articles from a corrosion standpoint? Do you feel or have evidence that the thin metal film corrosion indicator is subject to corrosion at humidities above this level and not subject to corrosion at humidities below this level?

Replies by David Roller:

Packaged articles are normally considered safe from a humid corrosive environment when the humidity level is kept below 40 percent. This dehumidification level is prescribed in Military Specification MIL-P-116 for the static desiccated preservation of materials. Dehumidified warehouse storage of ferrous and non-ferrous metals and materials of organic origin are also kept at or below 40 percent relative humidity. This humidity requirement was determined after a wide range of assembled materials and individual panels were exposed under controlled conditions for a number of years by several investigating groups particularly the Industrial Test Laboratory of the Philadelphia Naval Base. An excellent and thorough discussion on this subject can be found in a book by Greathouse and Wessel entitled "Deterioration of Materials, Causes and Preventative Techniques," Pages 274 and 721, Rheinhold Publishing Corporation, 1954.

As reported in this paper, thin metal films of iron on glass and plastic substrates will show initial visual corrosion in about 25 days and mild corrosion in about 35-40 days in a static humid environment of 40 percent relative humidity. By judiciously selecting metal film compositions, faster and slower rates of corrosion can be obtained. In comparative tests mild steel ribbons, SAE 1020, tarnished and mildly corroded in static humid environments of 40 percent relative humidity within from 8 to 12 months.

Development of the Redox Probe Field Technique*

By F. E. COSTANZO and R. E. McVEY

Abstract

A description is given of a field technique developed to obtain oxidation-reduction potentials of soils through the use of a probe. The results of all tests with this probe indicate that redox potential can be an extremely useful tool for corrosion engineers. The instrument is rugged enough for use in the field but sensitive enough to find even small indications of bacterial corrosion.

A comparison is made between redox data and the following items: (1) Pipe-to-$CuSO_4$ profile study, (2) Four-point soil resistance survey, (3) pH readings, (4) Earth current readings, and (5) Seasonal variation. 2.4.2

Introduction

IT HAS been the practice of corrosion engineers to refer to the corrosion of underground structures as being an electrochemical phenomenon. This practice was continued, even though experience has shown that at least one phase of corrosion was due to anaerobic soil bacteria, with the corrosion actually being primarily the result of sulfate reducing bacteria. In view of this the terminology should be corrected and underground corrosion referred to as an electro-biochemical process, the "bio" indicating the presence of a biological factor.

Starkey and Wight of the New Jersey Agricultural Experiment Station at New Brunswick, New Jersey, have made an extensive investigation of the use of the redox or oxidation-reduction potential of the soil as a criterion of anaerobic soil corrosiveness.[1] In their report of 1945, they stated that the probe used by them had not been found suitable, and furthermore that they knew of no suitable probe for making these highly desirable measurements in other than nearly liquid solutions. Accordingly, a PAR Plan project under the sponsorship of the American Gas Association, designated as PM-20, was assigned to Dr. Carl Deuber of the Deuber Laboratories of New York City. His problem was the development of a probe suitable for field use and capable of measuring this anaerobic tendency.

In April of 1956, Dr. Deuber published his findings and suggested a probe design for use in all types of soil.[2] The authors' problem was to adapt this probe to practical field use, and to obtain oxidation-reduction potentials by field techniques in order to ascertain the field practicability of redox readings obtained with this probe. This presentation will include a description of the field technique developed, together with the field readings of redox potential compared to other standard corrosion criteria.

Instrument Design

Figure 1 is a drawing of the various parts of the soil redox probe as developed from the basic design proposed by the American Gas Association Project PM-20. Because it was felt that the probe would have to be considerably more rugged for successful field operation, and because it is necessary, in field operation, to provide for quick and easy dismantling to effect repairs and replacement, certain minor changes were made in the original design.

Basically, the probe consists of a micarta tip with two platinum bands or ring electrodes and a lucite body housing the calomel cell or reference electrode. To ensure proper mounting of the platinum rings, the probe was machined and delivered to the platinum ring manufacturer for completion. It was felt that this method of manufacture would assure a good fit of the rings; however, even with this good fit it was thought desirable to use stop cock grease to ensure sealing at the rings on assembly. The surface area of the platinum electrodes was that recommended in the AGA report.[2] However, field experience with the probe has indicated that the surface area is not a critical dimension, nor is the distance between the electrodes and the calomel reference cell.

The reference electrode is a Coleman calomel cell (Catalog No. 3-043) having a screw cap. This type of cap construction lends itself readily to the desirable breakdown design of the probe. The liquid junction of this calomel cell, as used by the author, is a porous plug of balsa wood, instead of the ceramic plug proposed by Dr. Deuber. One of the problems of using a calomel cell for field operation is that the plug becomes contaminated to such an extent that the potassium chloride solution of the cell is discolored. When this happens the cell chamber must be drained, flushed out with distilled water, and the potassium chloride solution and plug renewed. Another problem in connection with the calomel cell is that when it is not in use, the cell capillary may become clogged with crystalline potassium chloride. To prevent this occurring, it is essential that when not in use the calomel cell chamber be filled with distilled water and the balsa plug replaced with a cork.

The working end of the assembled redox probe is shown in Figure 2. It is approximately 6½-inches long, and fastened to a 1-inch diameter polyvinyl chloride, Schedule 80, plastic pipe with a standard 1-inch plastic pipe coupling. Depending upon the depth at which readings are to be obtained, combinations of 3-foot lengths of pipe are used for ease of handling and storing for transportation.

Costanzo McVey

FRANK E. COSTANZO is senior corrosion engineer with the Manufacturers Light and Heat Co., Pittsburgh, Pa. He has been working on underground corrosion problems since 1945. Formerly with the Utility Survey Commission from 1936 to 1940, he has a BS in mechanical engineering from University of Pittsburgh, 1933. Mr. Costanzo is a member of the NACE board of directors representing the Northeast Region.

R. E. McVEY has worked on underground corrosion problems since 1955 as a member of the engineering department of the Manufacturers Light and Heat Co., Pittsburgh, Pa. He has a BS in biological science from Marshall College, Huntington, W. Va., 1951, and is a lieutenant in the naval reserve.

Preparations for Testing—Electrode Cleaning

Perhaps the biggest single problem in developing field technique for the use of this equipment was the development of a cleaning procedure for the platinum ring electrodes that would give reproducible data in a buffer test solution. The technique finally set upon consisted of washing the platinum electrodes with a strong household detergent, followed by three distilled water rinses. This combination has provided the most satisfactory method of preparing the probe for use.

The material needed to prepare the redox probe for tests consists of: (1) three wide-mouthed bottles, one containing a detergent and two containing distilled water, (2) a small bottle of saturated potassium chloride solution for filling the calomel cell chamber and (3) a rubber stopper with a 1-inch hole for slipping over the probe and of the proper outside diameter to fit the wide-mouth bottles.

Figure 3 shows the start of the cleaning of the electrodes. Prior to insertion in the detergent bottle, the probe was completely assembled, including filling the calomel cell with the potassium chloride solution and the insertion of the porous balsa wood plug. The rubber stopper was fitted to the probe in such a manner that it covered the balsa wood plug. Only the platinum electrodes in their assembly extended below the rubber stopper and into the detergent solution. By holding the probe in one hand and the bottle in the other, the operator can agitate the detergent by shaking.

The first two distilled water rinses were made by agitating the electrodes in the distilled water rinse bottles in the same manner as in the detergent. The third washing with distilled water was accomplished after removing the rubber stopper. In this case, distilled water from a plastic wash bottle was jetted over the entire electrode and plug assembly. The probe then was ready for use.

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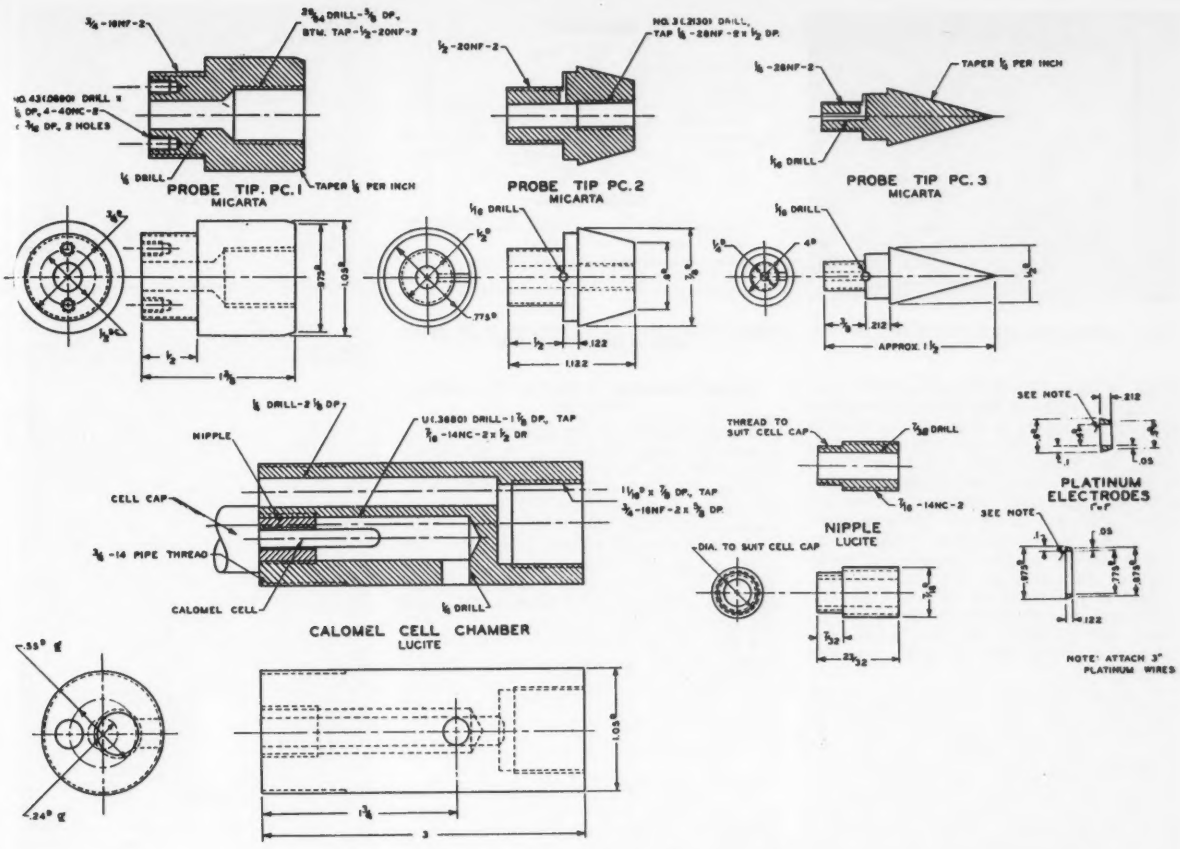

Figure 1—Drawing showing the various parts of soil redox probe.

Test Procedure

An M. C. Miller B-3 multi-combination meter was used for making the measurements obtained with the probe. If the potentiometer can be balanced with the platinum electrode connected to the negative terminal, the observed potential is negative. The time required to obtain a stabilized reading varies from a few minutes to as much as a half hour. The electrical potential obtained with the probe is referred to here as the "probe potential". It is known that the pH value of the soil affects the redox potential, so a correction factor is used to adjust this potential for the actual pH of the soil.[1] Because it is standard practice in the chemical industry to report redox readings against a hydrogen electrode, the reading obtained with this probe must be adjusted to the hydrogen electrode potential. The final corrected "redox potential" represents the potential of platinum referred to hydrogen at a pH value of 7.

Four ranges of indicator paper were used to obtain the pH value of the soil at the point of test. The paper used was Fisher Alkacid narrow-range pH paper. Attempts to use a Coleman Model 30 electrometer for making pH determinations in the field disclosed that technique to be cumbersome and slow, and the use of indicator paper was proven to be accurate enough for the adjustment necessary to arrive at the "redox potential". pH readings are obtained from soil that clings to the probe when it is removed from the test hole.

The technique of making the test is first to "bar" or auger a hole to a depth 4-inches short of that desired for the reading. The probe is then pushed or driven into place at the bottom of the barred or augered hole. Figure 4 displays all the equipment necessary for making redox readings.

It will be recalled from Figure 1 that there are two platinum rings on the nosepiece of the probe. In practice, this has been found to be highly desirable. In fact immediate readings are compared as quickly as possible on each of these cells as soon as the probe has been inserted to the desired depth. If there should be a substantial difference in the readings between the two cells, there is no need to wait for stabilization of potential. Instead the probe is withdrawn immediately, recleaned by the technique just described, and tried again in a fresh hole. Even after immediate potential readings are obtained that are in reasonably close agreement, the test is discarded if, after reaching stabilization of potential, there is a difference of more than approximately 50 millivolts in the potential attained with the two cells. The two readings are not considered separate readings in a redox probe survey. Instead, the median of the two readings is taken as the test data at that location. This is the figure which is known as the "probe potential".

Calculation and Interpretation of Redox Potential

The technique for converting "probe potential" to a reference hydrogen electrode is simple. It consists simply of adding 250 millivolts to the "probe potential". Correcting for pH deviation is just as simple. It consists of subtracting 60 millivolts per unit of deviation whenever the pH value is less than 7, and adding 60 millivolts per unit of deviation whenever the pH value is greater than 7.

Figure 2—Working end of an assembled redox probe.

Figure 3—Start of the cleaning of electrodes.

Figure 5 is a simple presentation of the correction factors and their application. E_h refers to redox potential. E_p refers to probe potential, the one obtained from the instrument as the test is made. E_r is the 250 millivolt correction to convert a calomel reference to a hydrogen reference. E_{pH} is the correction for pH value, (subtracted when the value is under 7 and added when the

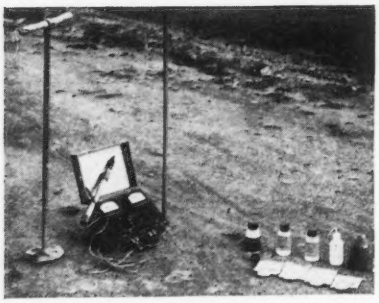

Figure 4—Equipment used in making redox readings.

CALCULATION

$E_h = E_p + E_r + E_{pH}$

E_h = REDOX POTENTIAL
E_p = PROBE POTENTIAL
E_r = +250mv CORRECTION OF CALOMEL REFERENCE ELECTRODE TO VALUE OF HYDROGEN
E_{pH} = CORRECTION TO pH 7 = 60mv PER UNIT OF pH DEVIATION FROM 7 ARE ADDED IF ALKALINE AND SUBTRACTED IF ACID

INTERPRETATION

E_h RANGE	DEGREE OF CORROSION
BELOW 100mv	SEVERE
100mv TO 200mv	MODERATE
200mv TO 400mv	SLIGHT
ABOVE 400mv	NON-CORROSIVE

Figure 5—Correction factors involved in the determination of redox potential.

value is above 7.) The actual pH range which will support the growth of sulfate reducing bacteria is from 5.5 to 8.5.[1] If the pH value of the soil falls within this range, the table shown in Figure 5 may be used to estimate the degree of bacterial soil corrosion tendency.[1] When the redox potential is below 100 millivolts, the tendency for corrosion is said to be severe. If the range is from 100 millivolts to 200 millivolts, then the tendency is said to be moderate. If it is from 200 millivolts to 400 millivolts, it is slight; above 400 millivolts, the soil is not considered to have any bacterial corrosion tendency.

It might be well at this point to run through a theoretical test station calculation. At the particular point where the test was made, assume that one cell read —283 millivolts and the other cell or electrode —315 millivolts. The difference between the two cell readings is 32 millivolts, which is accepted as being a satisfactory reading. The median point of the two readings is —299 millivolts. At this particular test site, it was found that the pH value of the soil sticking to the nose of the probe was 7.2. This is .2 above 7.0; the factor to correct for pH value was 60 millivolts for a whole unit, so .2 of 60 is 12 millivolts that will be added to the —299 millivolts to correct to a pH value of 7.0. Correction to a hydrogen electrode scale requires the addition of 250 millivolts to the test reading. To the original probe potential of —299 millivolts, +12 millivolts is added for the pH correction, and 250 millivolts for the hydrogen electrode correction; the algebraic sum of these is —37 millivolts. This is referred to as the redox potential. It is less than 100 millivolts, so by the general scale of classification this test location will be classified as having a tendency for severe bacterial corrosion.

Field Test Results

In order to compare redox readings with readings obtained by other standard forms of corrosion measurement it was decided to select for investigation approximately 1,000-feet of a bare welded 8-inch transmission line. This particular section of line was chosen for the comparative tests because it was laid in well-drained and poorly-drained soils, of high and low resistance. Also, it never had been subjected to cathodic protection.

The tests used for comparison were the conventional, pipe to Cu-$CuSO_4$ survey, a soil resistance survey using a 4-point Vibroground, earth current readings made with the McCollum earth current meter, and a pH profile using indicator papers.

Redox Potential vs Pipe to Cu-$CuSO_4$ Potential

Figure 6 compares the pipe to Cu-$CuSO_4$ potential taken directly over the pipeline, with the redox profile taken adjacent to the pipe at the same point along the pipe. Note on the top line of the diagram that the Cu-$CuSO_4$ profile indicates four distinct anodic areas: the first one at approximately Station 50, the second at approximately Station 400, the third at approximately Station 600, and the fourth at approximately Station 800. On the redox profile, note also that at Station 0 and at approximately Station 350-400 the redox profile is in agreement with the Cu-$CuSO_4$ profile. In both cases the redox reading is less than 100 millivolts, and the test areas thus would be classified as having severe bacterial corrosion tendency.

At Station 190 and again at Station 600, the redox profile indicates millivolt readings of approximately 400, which, by the general table of classification, would be classified as slight. The same general profile is indicated in the vicinity of Station 180 on both the redox and the Cu-$CuSO_4$ profiles. However, the difference in Cu-$CuSO_4$ potential between Station 180 and immediately adjacent points is so slight that under ordinary conditions it would not be considered to be an important anodic area. By Cu-$CuSO_4$ profile, the reading at Station 600 would be interpreted to be a definite anodic area, whereas the redox value places it at a "very slight" corrosive level. The redox reading at Station 800 is above 400 millivolts, and by the redox scale would not be considered to be a corrosive area; however, by the Cu-$CuSO_4$ test, this is indicated as an anodic area.

It is interesting to note that after the time of the first comparative tests and during the course of taking repeat tests along this pipeline at other seasons of the year, it was discovered that a leak had been repaired at Station 800 and a magnesium anode installed at the time of the repair. By the Cu-$CuSO_4$ profile, it was to be expected; by the redox profile, it would not be predicted.

Redox Potential vs Soil Resistivity

Before making a comparison of soil resistances, it might be well to consider the instrument used to measure soil resistivity in this comparative test. Figure 7 is a photograph of the 4-point Vibroground. Over the years this instrument has demonstrated its ability to accurately measure the highly variant soil resistivities encountered in pipeline work. Readings were taken at the same places as the Cu-$CuSO_4$ and redox tests.

Figure 8 is a comparison of the 4-point Vibroground profile with the

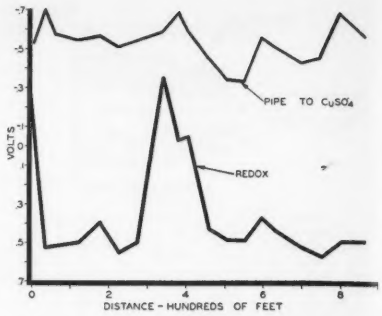

Figure 6—Comparison of pipe to Cu-$CuSO_4$ potential with redox profile taken adjacent to the pipe at t same point along the pipe.

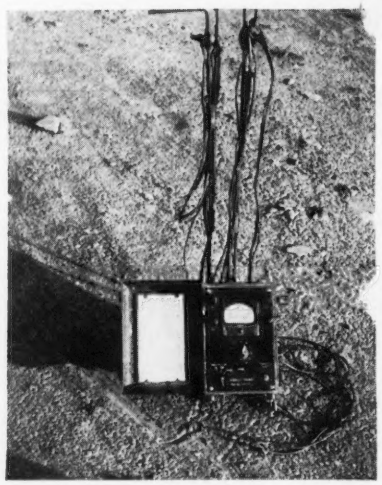

Figure 7—Four-point Vibroground.

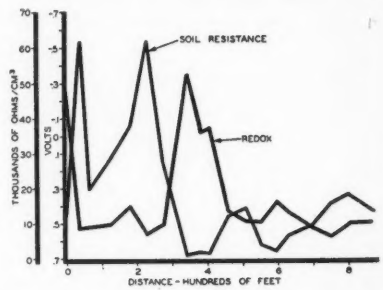

Figure 8—Comparison of 4-point Vibroground profile with redox potential profile.

redox potential profile. It should be noted at Station 0, and again at Station 350-400, that when the redox potentials are low, indicating severe bacterial corrosion tendency, the soil resistivity values are also low. At the same time, it should be noted that at Station 450 through 850 the soil resistivity was low and the redox potential was high. Thus it can be said that although there is low soil resistance where there are low redox potentials, low resistance in itself is not an indication of bacterial soil corrosion tendency.

Sufficient data are not available for it to be established that low soil resistance is one of the contributing factors which must be present under conditions of low redox potential. This profile ties in with

Figure 9—McCollum earth current meter.

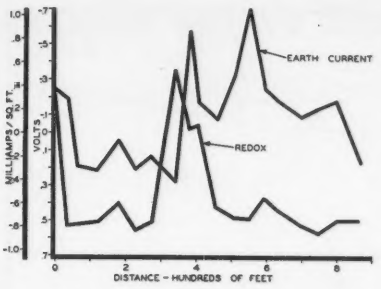

Figure 10—Earth current readings compared with redox potentials.

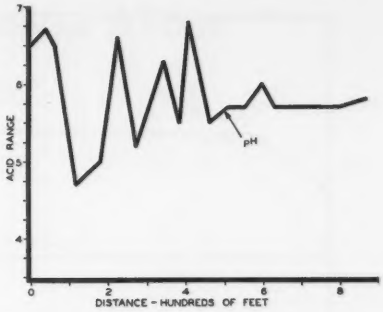

Figure 11—Plot of pH versus distance.

the Cu-$CuSO_4$ profile, however, in that areas of low resistance, compared to adjacent test points, conform closely to the anodic areas indicated by the Cu-$CuSO_4$ survey.

Redox Potential vs Earth Current Readings

Figure 9 is a photograph of the McCollum earth current meter used to obtain earth current readings along the pipeline as a comparison with the redox profile. Corrosion engineers of The Manufacturers Light and Heat Company have used this instrument for many years, and have found it to be an exceedingly valuable instrument for determing the magnitude of corrosion in areas along a line already in existence. Admittedly, it is an expensive instrument, and it is a difficult instrument process, but the results are well worth the expense and the trouble.

Readings were taken with a 4½-inch McCollum Earth Current Meter Electrode by "barring" or augering a hole directly to the top of the pipeline, being careful not to scar the pipe. Readings on the instrument are reported in milliamperes per square foot, with positive readings indicating current flow from the pipe and negative readings, current flow onto the pipe.

Figure 10 is a comparison of the profile along this test section, with earth current readings matched against redox potentials. The two areas of low redox potential readings, indicating severe bacterial corrosion tendency, are matched by earth current readings showing current flowing from the pipeline. In the case of the redox potential at Station 350 to 400, there is a slight displacement; within the same general area, however, there are earth current readings to match low redox potential in each case. There are also positive earth current readings at Station 550 and again at Station 800 which are not matched by low redox potentials. This again is a substantiation of the Cu-$CuSO_4$ and resistivity readings, when considered together with the fact that corrosion did occur at about Station 800. In this case, the earth current reading also matches the Cu-$CuSO_4$ reading at Station 180, but the pH value of the soil rules out the presence of bacteria and anaerobic corrosion. Three successive sets of comparisons have been made for these station locations at other points than 0 and 400, indicating the presence of corrosive conditions, probably not of bacterial origin.

pH Profile

Figure 11 is a plot of the pH value taken for purposes of correcting the probe potential. These data enable the observer to find those stations where the pH value is such that the bacteria could not exist. Notably, these are at such points as the small anodic area in the vicinity of Station 150. There is one other location at approximately Station 265; at Station 400 and Station 450 the soil is just barely within the range for bacterial propagation. The pH value at Station 120 to Station 180 was actually lower than 5.0. This in itself would be enough to produce a dissimilarity in electrolyte, accounting for the anodic area as indicated by Cu-$CuSO_4$ profile, resistivity, and earth current readings.

A Special Study Involving Redox Potential vs Pit Depth

At the same time that tests were started on the special 900-foot length of line in western Pennsylvania, there was also made available to the company a 3,000-foot length of 10-inch all welded uncoated line which had been laid near Westown, New York, in 1949. This portion of the line went through more than 1,500-feet of muck bed across a river, and then proceeded uphill onto well-drained ground. The line was scheduled to be exposed for inspection, a development which provided an opportunity for pit depth measurements. Accordingly, a series of comparative tests were taken along the length of this line, the results of which are shown on Figure 12. The top of the diagram is a strip map of the line with notations of the readings taken at various points along the line where redox potential, pit depth measurements, and pH value of the soil were measured. On the lower portion of the diagram is a plot of the Cu-$CuSO_4$ to soil potential, and the soil resistivity readings. Earth current readings also are shown for four places along the line.

Soil resistivity was uniformly less than 2000 ohms per cubic centimeter. Some magnesium anodes had been installed with this line when it was put in in 1949. This is indicated by the readings at Test Station 5+00, at Test Station 16+00, and again at Test Station 24+50. Of particular interest are the readings at Survey Station 12517+21, which is approximately Test Station 4+50. Note that the redox potential was —178 millivolts. This falls within the range to be classified as having severe bacterial corrosion tendency. The earth current meter shows a minus reading, indicating current flowing onto the pipe in small quantities, Cu-$CuSO_4$ potential is .95 volt; the pit depth attained in seven years' service is .08-inch. This could be interpreted overall as indicating a severe corrosion tendency by redox potential, a part of which tendency has been offset by the installation of a magnesium anode in the near vicinity. This single anode was not sufficient, however, to stop all corrosion. At the time of test, the earth current reading was negative; quite possibly, at other periods of the year, this becomes a positive reading.

Next consider Survey Station 12532+14, which is approximately Test Station 17+50, just on the west bank of the river. It will be noted that the redox potential is —28 millivolts, indicating a severe corrosion tendency due to bacterial action. The corresponding earth current meter reading is +.891 milliampers per square foot, and the Cu-$CuSO_4$ potential is approximately .9 volts. Pit depth here is .12 inches, which is considered to have been serious corrosion. It matches the redox potential and the earth current meter test. It should be remembered that this corrosion occurred in seven years. It is known from the Cu-$CuSO_4$ potential that there is an anode nearby, but it is nowhere near adequate to stop the corrosion at this point.

Immediately on the east side of the river, two redox test points were established, the western one for which there were no pit depth readings. A reading of —23 millivolts redox potential had been recorded, indicating an extremely severe bacterial corrosive tendency. Just 75 feet east of this station, at another redox test point, the redox potential was +497 millivolts and the maximum pit depth was .01 inch. This indicated that the author was now out of the bacterial corrosive tendency area. This was substantiated by the .01 inch maximum pit depth for seven years of corrosion.

A fifth set of readings were taken where the line crossed a small stream at Survey Station 12539+85, which was approximately Test Station 25+00. Again, the redox potential was +407 millivolts, far beyond any corrosive tendency for bacterial corrosion. The earth current meter showed a reading of almost 2.0 milliamperes per square foot flowing onto the pipe, and no pits could be found on the pipe.

Seasonal Variation in Redox Potential

Other investigations made by the Corrosion Department of The Manufacturers Light and Heat Company indicated some possibility of seasonal variation in corrosive tendency. This was strongly brought to the authors' attention by the results of a comparison between corrosion mitigation current requirements and weather on a section of

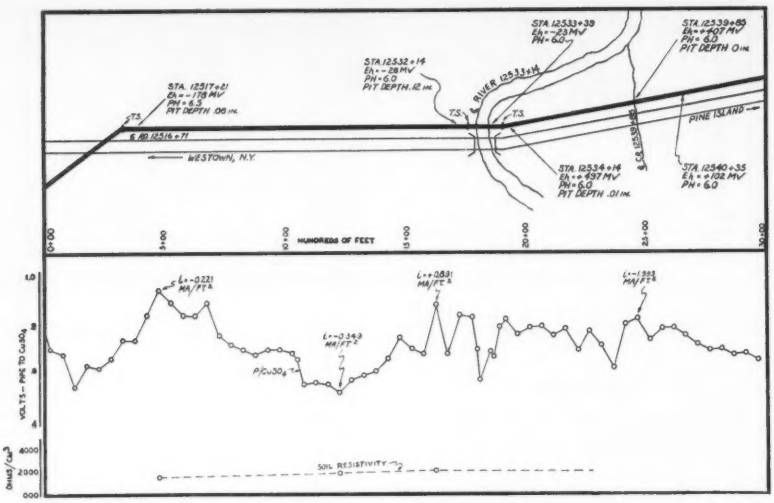

Figure 12—Strip map and corrosion survey of 10 inch uncoated line.

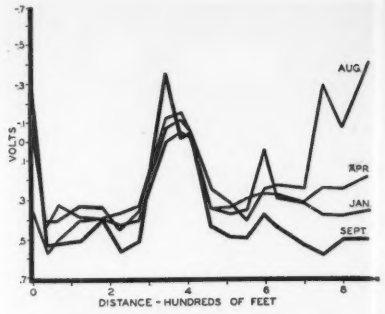

Figure 13—Seasonal redox surveys.

line which had been under observation for some seven years. Accordingly, after the first survey made on the test section of 1000 feet in September of 1956, redox potentials were rerun along this line in January, April, and August of 1957. The results of those tests are shown on Figure 13. The two outstanding low redox potential areas, Station 0 and Station 350 to 400, are consistently low redox potential points on all four occasions of test. The high redox potential points from Station 25 to 250 continue to be high redox potential stations, with reasonable variation from time to time. But on the portion of the line from Station 550 to 850, a considerable range of readings was obtained, depending upon the time of the year. For the first time, in August, low redox potentials were obtained at Station 750 and 850, where it was known there was a leak and where anodic areas were indicated by Cu-$CuSO_4$, resistivity, and earth current readings was obtained, depending upon sort of change occurred at Station 600 on the January test. The reason for the seasonal variation at these points are not yet known, although sufficient data are available on this curve to indicate that there are seasonal variations in the tendency for bacterial corrosion.

Conclusions

The results of all the tests with this probe indicate that redox potential can be an extremely useful tool for corrosion engineers. For lines already in service, it will pinpoint for them the causes of corrosion when the cause is bacterial action. For the investigation of areas in which it is proposed to lay a pipeline, it will pinpoint those locations where all of the conditions necessary for bacterial propagation are present. In both cases, it should be possible to indicate the severity of the corrosion tendency when it is due to bacterial causes. The present table proposed by Starkey and Wight is subject to confirmation by the continuance of many tests such as these. At least as far as this relatively small amount of data is concerned, the table seems to be reasonable.

A subcommittee of the Corrosion Committee of the American Gas Association has been assigned the specific task of investigating the validity of the gradations of corrosion proposed in the present table. It is hoped that by collecting a multitude of data which compares complete surveys by redox probe with Cu-$CuSO_4$ potential, soil resistivity, and earth current readings, that either this table will be verified or some other table devised. To be of value, the proposed data must not be isolated, with a single reading here, another 2,000 feet away, or on another pipeline. To be of value, the data must be continuous.

The results of these tests are sufficient to indicate that an instrument has been developed which is rugged enough for use in the field. It is sensitive enough to find even small tendencies of bacterial corrosion, but like any other instrument, it must be used with discretion. The device does not appear to be the panacea to solve all of the corrosion engineer's test problems. It is simply another useful tool to be added to those already on hand.

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2. C. G. Deuber and G. B. Deuber. Development of the Redox Probe. Final report of the American Gas Association Research Project PM-20, New York, pp. 23 (1956).

Any discussions of this article not published above will appear in the December, 1958 issue

Corrosion Resistance of Five Stainless Alloys In Nitric Acid Containing Chloride*

By I. I. TINGLEY

Abstract

A number of stainless steels and the new alloy Ni-O-nel were tested in solutions 8N in HNO_3 and 0.2N in chloride. Stainless steels Types 304L, 316, 309SCb, and 329 were all resistant to the liquid and hot vapor, but only Type 329 showed good resistance to the condensing vapors from these solutions. The resistance of this steel was about 1000 times as great as that of Types 304L, 316 and 309SCb.

4.3.4

Introduction

THE WORK reported here was undertaken as the result of a proposal to concentrate a nitric acid solution of fission products in the Chemical Extraction Plant for the NRX reactor at Chalk River. The solution was to be evaporated in an existing evaporator of Type 316 stainless steel. The main constituents of the boiling solution at steady evaporation would be approximately 8N nitric acid and 0.2N chloride. A severe corrosion problem was anticipated because of the relatively high concentrations of chloride to be expected in the condensing vapor. An analysis of the problem on the basis of data furnished by the work of Haggerty and Hixon[1] indicated that a 2- to 3-fold concentration of chloride might be expected in the condenser of the evaporator. The expected nitric acid content of the condensate was approximately 1.6N.

Corrosion tests were made on samples of Type 316 steel from the evaporator to determine the magnitude of the corrosion problem. A decision was made to test also several other high alloy steels with a view to finding those exhibiting the greatest resistance to corrosion by condensing vapor from the above solution. A brief report of the results of this investigation is given below.

About the Author

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Apparatus

The apparatus shown in Figure 1 was constructed to test the steels under three conditions representative of the evaporator system. Specimens were tested as follows: (a) totally immersed in the boiling liquid, (b) suspended in the vapor phase in the flask, and (c) suspended below the condenser, in the path of the incoming hot vapors. The solution in the flask and the condensate were sampled at the beginning and end of each run, and at intervals during the run. The majority of runs were of 60 hours' duration. The following steels were tested: stainless steels Types 316, 304L, 309SCb and 329. A test also was made on Ni-O-nel. Analyses of the alloys tested are given in Table 1.

The specimens were 1" x ½". Thicknesses varied for the different alloys from 0.193" to 0.25". Holes ¼" or ⅜" in diameter were drilled near one end of the specimens depending on whether they were to be suspended in the flask or in the condenser. They were degreased in acetone, and with the exception of a single batch of Type 329 specimens, were pickled. This was accomplished by immersing specimens in a solution containing 28 gm of NaCl and 66 ml of concentrated H_2SO_4 per liter for 20 minutes at 70 to 75 C, followed by immersion for 10 minutes in a solution containing 70 ml concentrated HNO_3 and 8.8 ml concentrated HF per liter at 60 to 65 C. Specimens were then rinsed, dried for one hour at 110 C, and weighed before testing. At the end of the run they were rinsed with tap water, brushed with a soft brush, rinsed with distilled water, dried, and weighed. For convenience in comparing results the weight losses in the test periods were expressed in terms of penetration in mils per year even for samples on which the attack obviously had not been uniform.

Results

The data obtained in these tests are given in Tables 2 and 3.

A similar test on Type 329 specimens (pickled) in the condensate was continued for 384 hours, and the corrosion rate for this period was found to be 0.7 mils per year.

The effect of a higher chloride concentration in the boiling solution is shown in Table 4, which gives corrosion rates obtained with Type 329 steel in the condensate when the solution in the flask was 7.8N in HNO_3 and 0.45N in chloride. It was observed that the greatest part of this corrosion occurred in the first 10 hours of the test.

Discussion

Stainless steel Type 329 has a corrosion resistance remarkably greater than that of stainless steels Types 316, 304L and 309SCb and Ni-O-nel for the conditions prevailing in this test. When totally immersed, or in the hot vapors without reflux, Types 316 and 309SCb also have good resistance, but in the condensing vapors all alloys tested except Type 329 are severely corroded. The specimens become honeycombed with pits until they have a porous ap-

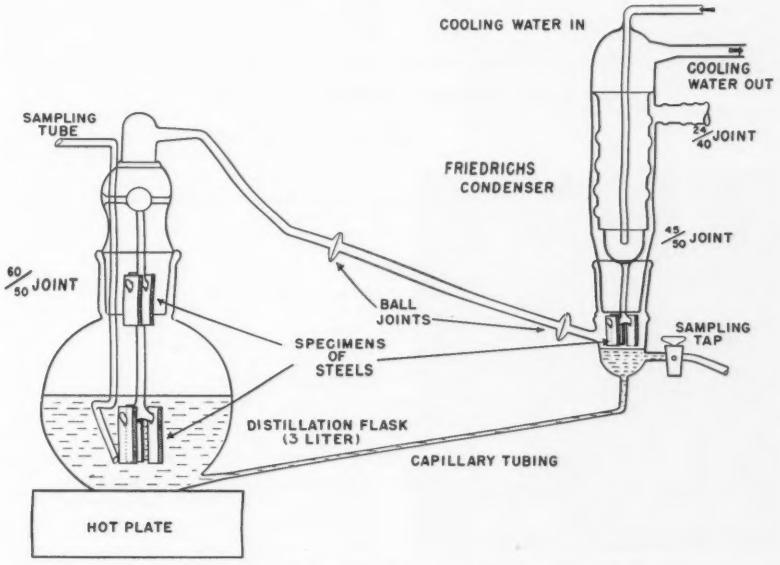
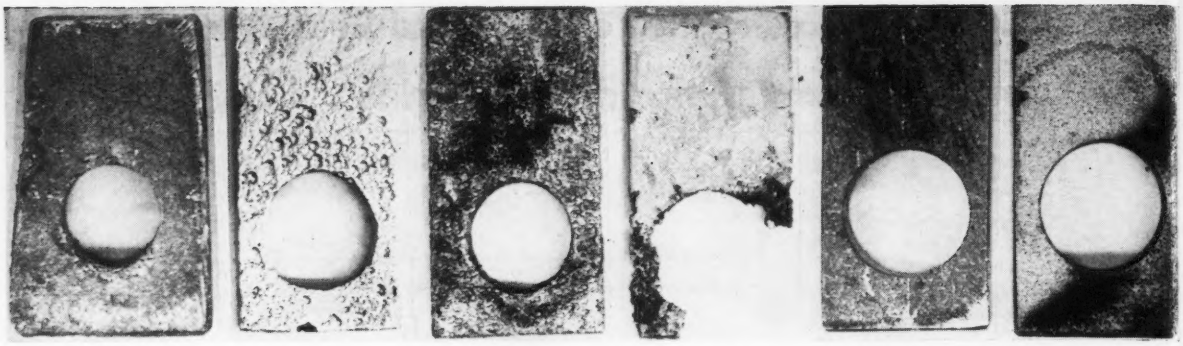


Figure 1—Apparatus for testing corrosion of stainless steels in HNO_3-HCl solutions.

* Submitted for publication July 19, 1957.



316 304L 309 SCb Ni-O-nel 329 (unpickled) 329 (pickled)

Figure 2—Typical specimens after 60 hours in the hot condensate from boiling 8 N nitric acid containing 0.2 N chloride.

TABLE 1—Analyses of Alloys Investigated

Type of Alloy	PERCENTAGES						
	C	Cb	Mn	Cr	Ni	Mo	Other
316	0.086	.....	1.45	17.52	13.05	1.89	Balance, Fe
304L	0.03	.....	1.22	18.76	10.22	.....	P-0.027, S-0.017, Si-0.017, Balance Fe
309SCb	0.04	0.58	1.4	22.3	15.4	.....	Balance, Fe
Ni-O-nel	0.05	.....	0.60	21	40	3.0	Fe-31 Cu-1.75
329	0.091	.....	0.76	27.48	4.25	1.50	P-0.017, S-0.015, Si-0.55, Ti-0.28, Balance-Fe

TABLE 2—Chemical Analysis of the Corrosion Environment

	TYPE OF STAINLESS STEEL OR ALLOY					
	316	304L	309SCb	Ni-O-nel	329 (Unpickled)	329 (Pickled)
Duration of Test, Hrs.	64	60	60	60	60	60
Acid in Flask, Initial, N	7.4	7.6	7.9	7.8	7.7	7.5
Acid in Flask, Final, N	7.8	7.6	8.1	8.1	7.4	7.5
Acid in Condenser, Initial, N	1.06	1.5	1.6	1.86	1.29	1.22
Acid in Condenser, Final, N	1.80	1.1	1.6	2.13	1.10	1.62
Cl^- in Flask, Initial, N	0.20	0.16	0.16	0.19	0.17	0.18
Cl^- in Flask, Final, N	0.20	0.16	0.16	0.18	0.16	0.15
Cl^- in Condenser, Initial, N	0.40	0.74	0.65	0.87	0.46	0.54
Cl^- in Condenser, Final, N	0.86	0.45	0.65	0.69	0.36	0.74

TABLE 3—Corrosion Rates in Mils Penetration per Year

	TYPE OF STAINLESS STEEL OR ALLOY					
	316	304L	309SCb	Ni-O-nel	329 (Unpickled)	329 (Pickled)
Duration of Test (Hours)	64	60	60	60	60	60
Liquid Specimen						
No. 1	12	105	5	52	7	4
No. 2	12	47	5	54	7	4
No. 3	12	71	4.5	53	6	4
Vapor Specimen						
No. 1	6	3	2	25	6	2
No. 2	6	2	2	25	5	2
No. 3	6	3	2	28	6	2
Condenser Specimen						
No. 1	803	1560	711	1410	630	0.3
No. 2	243	1720	640	1190	1460	0.4
No. 3	726	476	392	300	13	0.4

pearance like coke, and pieces may crumble and break away. Figure 2 shows the porous and pitted surfaces of Types 316, 304L, 309SCb and Ni-O-nel after testing, and shows the surface of a pickled specimen of Type 329, unchanged after testing except for superficial stains.

Table 2 shows that the acid and chloride concentrations changed in some tests during the run, particularly in the condenser. No simple explanation of this is known, since sometimes the concentrations increased and sometimes they decreased. The fact that this occurred even in the tests with Type 329 indicates that it is not a result of reaction with the specimens, but more likely is due to the design of the apparatus and the operating conditions.

It has been brought to the author's attention that Type 329 in acetic acid service, though showing excellent resistance in short-term tests, corroded intergranularly after some time, as a result of preferential solution of the sigma phase.[2] Metallographic and X-Ray examination of the Type 329 steel used in these tests revealed no sigma phase present. Further tests of longer duration and with chloride concentrations intermediate between 0.2N and 0.45N are being carried out.

TABLE 4—Results of Tests on Triplicate Specimens of Type 329 Stainless Steel at Higher Chloride Concentrations

Specimen No.	Rate, Mils/Year
1	1460
2	1340
3	240

Note: Total time of exposure was 60 hours; analysis of condensate at beginning was as follows: Acid—3.7N, Cl^-—1.95N; analysis of condensate at end was as follows: Acid—2.5N., Cl^-—1.21N.

Conclusions

This investigation has shown that stainless steels Types 316, 304L, 309SCb and Ni-O-nel are all corroded severely by condensing vapors from solutions 7.5 to 8N in HNO_3 and 0.2N in chloride, but Type 329 shows good resistance in this environment, at least up to 384 hours. This indicates the feasibility of using this material in the condenser of an evaporator boiling solutions of 8N nitric acid with 0.2N or less chloride.

Acknowledgments

The author expresses his indebtedness to Dr. F. H. Krenz, who directed this work, and to L. P. Trudeau of the International Nickel Company of Canada, Ltd., for much helpful discussion.

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Laboratory Testing of Railroad Diesel Cooling System Corrosion Inhibitors*

By J. I. BREGMAN and D. B. BOIES

Abstract

The cooling system of a railroad Diesel locomotive presents a complex corrosion problem, due to the number of different metals used and the wide range of conditions encountered. These factors are discussed in relation to the development of test methods for the laboratory evaluation of corrosion inhibitors.

Two types of tests were developed: a flask type test for screening and development work, and a recirculating test, including a heat transfer surface, designed to more nearly duplicate the actual use conditions, and to give a final evaluation to a product.

Test results are given for several commercial and experimental inhibitors of the "boron-nitrite," "soluble oil" and other types. Results are also presented for variation of factors such as coupling or insulation of the various metals, inhibitor dosage level, water composition, presence of anti-freeze, etc., as well as effect of the treatment on various non-metallic parts of the system.

The importance of inhibition behavior under these various conditions is discussed in relation to actual use conditions. It is shown that the results of the laboratory tests have correlated well with field use. 2.3.4

Introduction

CORROSION IN railroad Diesel cooling systems can lead to the necessity for major overhauls in relatively short periods of time. As a result of the loss of metal, leaks may be developed which cause loss of cooling water. Leakage of the cooling water into the crankcase, plugging of radiators with corrosion products and a decrease in heat transfer efficiency all may contribute to rapid deterioration of the engine.

There are a number of different makes of Diesel engines in use today. All major Diesel locomotive builders specify that corrosion inhibitors must be used in the cooling water. In some cases, rather strict requirements are laid down as to the types of treatments and the concentrations which are to be maintained. It also is generally understood that treatments used should not attack rubber hose connections, seals, and cylinder head gaskets or corrode fitted joints.

In studying a problem of this type, consideration must be given to the conditions which are critical insofar as corrosion is concerned. The metals which corrode vary over a wide range and generally include cast iron, steel, copper, brass, and various other alloys and solders. These metals may behave either as if they are coupled to or insulated from the rest of the system depending on the location.

Non-metallic components which must not be attacked include natural and synthetic rubbers, carbon, and asbestos. Temperatures will vary from ambient (when the engine is first started up) to about 180 F under normal operation. Recently this range has been extended with the introduction of vapor phase cooling.[1]

Waters which may be used in cooling systems vary in composition with geographical location. Soft clear waters containing no higher than 10 grains per gallon of total hardness or sodium chloride are preferred, but frequently waters with an excessively large amount of hardness find their way into cooling systems, and a considerable amount of scaling results. Pressures range from atmospheric to about 15 psig. The velocity of the water in the cooling system may be anywhere from stagnant up to an estimated value of 5 to 10 ft/sec.

Field conditions and practices often vary widely from railroad to railroad and may vary even from one division to the next for some railroads. A small amount of leakage of cooling water is common, and sometimes such conditions are not remedied until they become serious. This results in a need for abnormal replenishment of the cooling water (and inhibitor).

Bregman Boies

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DAVID B. BOIES received a BS in chemical engineering from the Illinois Institute of Technology in 1949. Since that time he has been with the National Aluminate Corp., Chicago, Illinois, engaged in research and development of corrosion inhibitors. For the past several years his work has been concerned with corrosion in the various phases of the petroleum industry.

Inhibitor concentration may be determined by various accepted test methods at some locations, and neglected at others. Waters which are either very high or very low in dissolved solids and hardness may be added at watering points. Railroad personnel responsible for cooling water treatment maintenance will change in training and interest from one location to the next. Anti-freeze liquids may be used in some units. All this indicates that the corrosive conditions and the control of inhibitor concentration vary widely, and points up the need for corrosion inhibitors which still will give good protection under such conditions.

In addition to the electrochemical corrosion which would normally be encountered, some types of engines are subject to cavitation erosion. There is considerable dispute as to the mechanism of this type of attack, but there is general agreement that it probably is strongly dependent on the design of the engine and liners, the flow pattern of the liquid, and vibration. The role of electrochemical corrosion in this case is in considerable doubt, but it can certainly be an undesirable factor. Cavitation erosion was not included in the testing reported here.

In the development of laboratory test procedures for corrosion problems, considerable attention must be given to the factors which may contribute to the field corrosion problem. While it is not necessary, and indeed often impossible, to duplicate the field set-up, it is vital that the corrosion conditions of the field problem be reproduced in the laboratory testing units. For this reason, a number of different test procedures were used in the development of suitable inhibitors for Diesel cooling systems. These tests were designed so as to include the effect of the following factors:

1. Static conditions
2. Recirculating conditions
3. Coupled metals
4. Non-coupled metals
5. Aluminum, brass, radiator tubing, copper, solder and cast iron specimens of the type used in actual Diesel cooling systems
6. Heat transfer surfaces

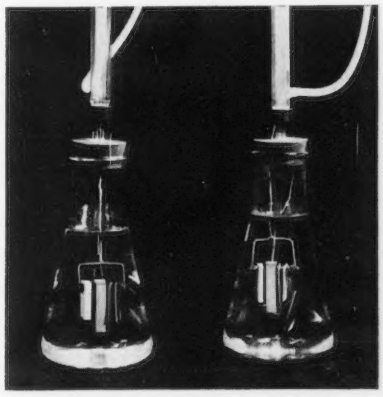

Figure 1—Flask corrosion test apparatus. Uncoupled (left) and coupled (right) types are shown.

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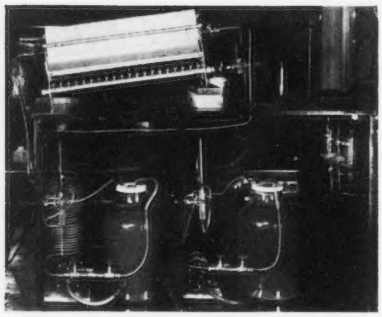


Figure 2—Recirculating corrosion test apparatus.

TABLE 1—Reproducibility of Coupled Test Procedure*

METAL	CORROSION RATES (mpy—mils per year) 1st Test	2nd Test	3rd Test	Ave.
Cast Iron	0.3	0.4	0.3	0.3
Aluminum	12.0	13.8	8.3	11.4
Solder	1.0	0.9	0.8	0.9
Copper	0.1	0.1	0.1	0.1
Brass	0.3	0.1	0.3	0.2

* Flask Test, 7 Days, 180 F; Treatment = Inhibitor "A" at 0.75 oz/gallon.

TABLE 2—Range of Results With Coupled Test*

Metal	Range of Corrosion Rates (mpy)
Cast Iron	0.1 to 30
Aluminum	1.0 to 80
Solder	0.0 to 12
Copper	0.0 to 8
Brass	0.0 to 8

* Flask Test, 7 Days, 180 F.

7. Various types of rubber hose seals, and gasketing materials found in Diesel cooling systems
8. Temperatures from near freezing to near boiling
9. Aeration
10. Variation in inhibitor concentration
11. Variations in water compositions so as to cover field waters
12. Different types and amounts of anti-freeze materials
13. Compatibility of different inhibitors
14. Time

Experimental

There are two basic experimental test procedures used, which are hereafter referred to as the flask and recirculating tests. Details of these test procedures are as follows:

Flask Type Tests (Figure 1)

1. Apparatus. The flask type test was run in a wide mouth 1 liter flask, equipped with a reflux condenser and an aeration tube. The aeration tube was made of 2 mm glass tubing, and was surrounded by a glass chimney to prevent impingement of the air on the specimens. The specimen assembly was supported in the solution by hooks of Nichrome wire. The flask was immersed in an oil bath at the desired temperature.

2. Test Solution. Test solutions were made up in a corrosion test water consisting of one part Chicago tap water to one part distilled water, with 10 grains of sodium chloride added per gallon. One liter of solution was used, and the temperature was maintained at 180 ± 5 F.

3. Specimens. The specimens used were picked for their similarity to metals used in Diesel cooling systems. The specifications for each specimen were as follows:

(a) Brass—The brass specimens were strips measuring 1 inch by 1½ inch by 1/16 inch. The composition is given by specification SAE 70 grade C.

(b) Copper—The copper specimen consisted of a strip measuring 1 inch by 1½ inch by 1/16 inch, conforming to specifications ASTM B133-47T.

(c) Solder—The solder specimen consisted of a piece of either 9 or 10 B & S gauge solid solder, having a surface area of 2.2 square inches. One end was flattened and a mounting hole drilled. The composition of the solder was 45 percent tin and 55 percent lead. The specimen was bent in the form of a loop.

(d) Aluminum—The aluminum specimens used in these tests were made from cast strips of Alcoa 319 alloy. These specimens were milled to 1 inch x 1¼ inch x 3/16 inch.

(e) Cast Iron—The cast iron specimens were supplied by a locomotive manufacturer, and were cut from a Diesel cylinder liner. They were of a typical nickel cast iron, having an approximate analysis as follows:

Total Carbon	3.1 percent
Combined Carbon	0.5 percent
Manganese	0.8 percent
Silicon	1.9 percent
Chromium	0.3 percent
Nickel	1.3 percent
Molybdenum	0.4 percent

The specimens measured approximately 1 inch by 2 inch by 3/8 inch. If the inner wall were chrome-plated, the plating was removed by milling.

(f) Radiator Tube—The radiator tubing specimen was 1½ inch in length and was cut from Diesel radiator tubing. It was made of brass (85 Cu-15 Zn) coated with tin.

These specimens were used in all of the flask tests reported here. The area of the specimen to the volume of liquid ratio is as follows:

Specimen	Square Inches Per Gallon
Cast Iron	23
Aluminum	15
Solder	8
Radiator Tube	10
Copper	11
Brass	11

4. Procedure.

a. Coupled. After preparation, the specimen were weighed, and then mounted on a 6-32 brass screw, separated about 1/8 inch by conical brass washers, so that they were in electrical contact. They were placed on the bolt in the following order: solder or radiator tube, cast iron, copper, brass, and aluminum. The assembly was then placed in the test solution at 180 F, being suspended from the Nichrome hooks. After one week, the specimens were removed, cleaned and reweighed. The extent of corrosion was determined by weight loss and/or visual examination.

Specimens were prepared as follows:

Cast Iron, Aluminum, Copper, Brass—Sand blasted, wiped with dry cloth; then rinsed in acetone and toluene

Solder—Rubbed well with a rag wet with toluene.

Radiator Tube—Cleaned first with toluene, and washed with soap and water.

Specimens were cleaned after test as follows:

Cu and Brass—Washed with water, dipped in inhibited HCl for 15 seconds, and then dipped in soda ash and rinsed with water.

Solder and Radiator Tubing—Washed lightly with Babo, and then rinsed and dried.

Cast Iron—Cleaned with soap and water, dipped 30 seconds in inhibited HCl, then in soda ash solution, and finally rinsed and dried.

Aluminum—Immersed at 180 F in 2 percent CrO_3 + 5 percent H_3PO_4 solution for 10 minutes.

Cleaning losses were as follows:

Copper	0.3 mg
Brass	0.2 mg
Aluminum	0.2 mg
Cast Iron	0.4 mg
Solder	0.5 mg
Radiator Tube	0.5 mg

b. Uncoupled Flask Tests. The tests were run in distilled water, and the specimens were insulated from each other by suspending them on a glass rod with rubber spacers. The solutions were aerated, at 180 F, and the test period was one week. The specimens were radiator tube, cast iron liner, copper, brass, and aluminum. Testing conditions and procedures otherwise were identical with the coupled flask tests.

Recirculating Tests (Figure 2)

The recirculating test was designed to more nearly duplicate actual conditions in a Diesel cooling system, and to give a final laboratory evaluation of a treatment. Water was circulated by means of a centrifugal pump from a 5 gallon glass reservoir through 50 feet of ¼ inch copper tubing, then through a 3 foot length of 9/16 inch, 20 gauge, cold drawn seamless steel tubing, and back to the reservoir. The steel tube was heated by means of several Bunsen burners to maintain an effluent temperature of 180 F, thus providing a heat transfer surface. The copper tubing coil served to radiate heat. Flow through the system was approximately 0.4 gallon/minute. The copper coil and the steel tube were in electrical contact.

Specimens of the type used in the flask test were suspended in the reservoir. One set contained all five metals in contact, as described above. The second set was the same, except that the aluminum specimen was not present. The third set contained all five metals electrically insulated from each other by means of rubber washers on a glass rod. Regular test water was used. After the test, the specimens were cleaned and reweighed to determine weight loss. Corrosion and scale formation were determined at the heat transfer surfaces by cutting the tube on a di-

TABLE 3—Uninhibited Corrosion Rates*

Metal	CORROSION RATES (mpy)			
	Coupled	Range	Insulated	Range
Cast Iron	18.6	15-20	10.2	8-12
Aluminum	18.3	14-22	7.8	6-11
Solder	0.6	0.4-0.7	.....	.....
Radiator Tube	.....	.....	0.2	0.1-0.3
Copper	0.3	0.2-0.4	0.7	0.5-0.9
Brass	0.3	0.2-0.4	0.7	0.5-0.9

* Flask test was conducted for 7 days at 180 F.

TABLE 4—A Comparison of Results Obtained With the Two Different Test Procedures*

Metal	CORROSION RATES (mpy)				
	FLASK TESTS		RECIRCULATING SYSTEM		
	Coupled	Insulated	Coupled	Coupled	Insulated
Cast Iron	0.5	0.4	0.4	0.5	0.8
Aluminum	1.9	0.5	7.7	.....	8.5
Solder	0.5	.....	0.1	4.7	.....
Radiator Tubing	.....	0.0	.....	.....	0.3
Copper	0.5	0.7	0.1	0.7	0.7
Brass	0.3	0.2	0.5	0.7	0.8

* Seven days at 180 F. Treatment = Inhibitor "B" at 0.75 oz/gallon.

TABLE 5—Effect of Concentration of Inhibitor on Protection*

Metal	Inhibitor	Corrosion Rates (mpy) At Inhibitor Conc (oz/gal) of:		
		0.3	0.75	1.5
Cast Iron	"C"	0.3	0.4	0.4
Aluminum	"C"	9.7	5.1	4.1
Solder	"C"	**	1.0	0.2
Copper	"C"	0.3	0.3	0.3
Brass	"C"	0.3	0.0	0.3
Cast Iron	"D"	1.5	0.5	0.4
Aluminum	"D"	43.5	9.0	6.2
Solder	"D"	2.0	0.6	0.2
Copper	"D"	0.8	0.3	0.1
Brass	"D"	0.8	0.3	0.1

* Coupled flask test, 7 days at 180 F.
** Indicates slight gain in weight.

TABLE 6—Effect of Water Composition on Corrosion Inhibition*

Metal	CORROSION RATE (mpy):			
	Chicago Tap Water	Standard Test Water	30 gpg NaCl Water	50 gpg NaCl Water
Cast Iron	0.4	0.5	0.6	0.6
Aluminum	2.8	9.0	34.7	52.5
Solder	0.5	0.6	0.6	1.1
Copper	0.2	0.3	0.9	0.1
Brass	0.1	0.3	0.3	0.2

* Coupled Flask Test, 7 Days at 180 F. Treatment = Inhibitor "D" at 0.75 oz/gallon.

TABLE 7—Corrosion Inhibition by "Soluble Oil" and "Boron-Nitrite Type" Inhibitors*

Metal	CORROSION RATES (mpy)					
	Inhibitor "E" (Soluble Oil) In Dosages of (fl. oz/gallon)			Inhibitor "C" (Boron-Nitrite Type) In Dosages of (oz/gallon)		
	0.5	1.0	2.0	0.3	0.75	1.5
Cast Iron	0.7	0.9	**	0.3	0.4	0.4
Aluminum	12.5	1.4	**	9.7	5.1	4.1
Solder	1.0	2.7	20.0	**	1.0	0.2
Copper	5.3	2.9	2.9	0.3	0.3	0.3
Brass	3.6	4.5	4.9	0.3	0.0	0.3

* Coupled Flask Test, 7 Days, at 180 F.
** Indicates gain in weight.

agonal, and observing that part of the tube which was directly over the flame.

Inhibitors used in this work are as follows: A, B, C, D and G—non-chromate "boron-nitrite" types; E—Commercially available "soluble oil" type; H. J. K, L—Commercially available automobile radiator rust inhibitors. The composition of these proprietary inhibitors is unknown. None appeared to be based on chromate; all four were liquids.

Rubber hoses and gasketing material tested were obtained from Diesel locomotive manufacturers.

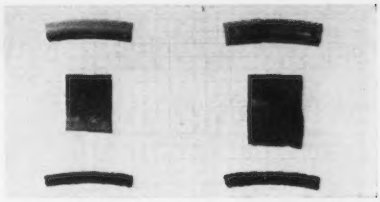
Results and Discussion

One of the requirements of a satisfactory testing procedure is that it show good reproducibility: Table 1 gives the results of three identical coupled flask tests using inhibitor "A" at 0.75 oz/gal. These tests show good reproducibility. This is further brought out by comparison of these values with those in Table 2 which show the range of corrosion rates (for the coupled flask procedure) encountered in several hundred tests of this type. These tests include blanks, and different additives at different dosages. The uninhibited corrosion rates are shown in Table 3. It can be seen by comparing the values in Tables 2 and 3 that the uninhibited corrosion rates were not the highest that were encountered during the testing. Quite often a material being tested as an inhibitor would reduce the corrosion rate of one metal, but would accelerate the corrosion rate of one of the other metals.

The corrosion rates which may be considered acceptable for an inhibitor will vary according to the metal. Metals which may be present in thin sections, at joints, or in valves, such as radiator tubing, copper, brass, or solder, should have the corrosion rates held to the range of one mpy or less. Cast aluminum and cast iron, which are present in thicker sections can tolerate rates up to four mpy, if the corrosion is general. However, iron corrosion also may be troublesome from the standpoint of blocking the passageways due to the accumulation of corrosion product. For this reason the rate for cast iron should be held to a lower value than that which would be dictated by danger of actual penetration.

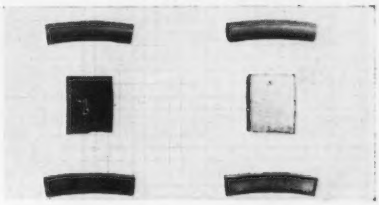
The reported rates are based on the total specimen area, so if the attack is localized, the actual penetration rate will be higher than the indicated corrosion rate.

The reproducibility found for the uncoupled flask tests and the recirculating system tests was of the same order as that of the coupled flask tests. In general, uncoupled flask tests were somewhat less severe than the coupled flask tests, while both coupled and uncoupled recirculating tests tended to be somewhat more severe than their static analogues. This is shown in Table 4



As Received — After Two Weeks Treatment

Figure 3—Effect of "soluble oil" inhibitor "E" on samples of Diesel gaskets and radiator hose.



As Received — After Two Weeks Treatment

Figure 4—Effect of "boron nitrite" inhibitor "G" on samples of Diesel gaskets and radiator hose.

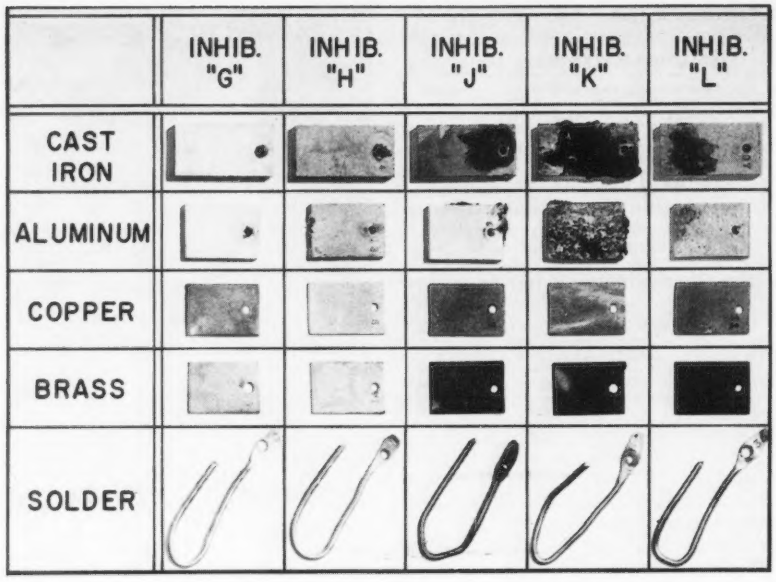


Figure 5—Corrosion tests with commercial inhibitor (with coupled specimens). Corrosion rates are given in Table 8.

TABLE 8—Comparison of Commercial Inhibitors*

Metal	CORROSION RATES (mpy) AT INHIBITOR DOSAGES RECOMMENDED BY MANUFACTURERS				
	Inhibitor "G" at 0.75 fl oz/gallon	Inhibitor "H" at 1.0 fl oz/gallon	Inhibitor "J" at 4.0 fl oz/gallon	Inhibitor "K" at 4.0 fl oz/gallon	Inhibitor "L" at 4.0 fl oz/gallon
Cast Iron	0.4	0.7	2.4	5.5	0.6
Aluminum	4.2	25.6	39.8	22.8	9.8
Solder	0.8	2.3	2.2	0.4	1.0
Copper	0.3	0.0	0.7	0.6	1.6
Brass	0.1	0.3	1.2	0.7	1.6

* Coupled Flask Test, 7 Days at 180 F.

TABLE 9—Flask Tests in Presence of Methanol (50 Percent)*

Material	Length of Tests	Corrosion Rates in mpy When Coupled		Corrosion Rates in mpy When Insulated	
		No Inhibitor	Inhibitor "G" at 0.75 oz/gallon	No Inhibitor	Inhibitor "G" at 0.75 oz/gallon
Cast Iron	7 Days	19.0	1.0	15.4	1.0
Aluminum	7 Days	0.4	0.6	12.4	1.9
Solder	7 Days	0.2	0.2	....	....
Radiator Tube	7 Days	....	....	1.5	0.0
Copper	7 Days	0.1	0.2	1.6	0.1
Brass	7 Days	0.2	0.1	0.8	0.2
Cast Iron	30 Days	19.3	0.1	12.7	0.1
Aluminum	30 Days	1.4	0.3	2.2	0.1
Solder	30 Days	0.1	0.1	....	....
Radiator Tube	30 Days	....	....	0.7	0.0
Copper	30 Days	0.2	0.1	1.5	0.1
Brass	30 Days	0.1	0.0	0.8	0.1

* Flask Test, 140 F.

which compares corrosion rates for inhibitor "B" under all the test conditions. A similar relationship of results was found for all other inhibitors which were tested by both flask and recirculating procedures. The reason for carrying out two different coupled tests in the recirculating system tests is that the aluminum-iron couple may, in some cases, produce heavy aluminum corrosion which protects the iron in a "sacrificial anode" type protection. Removal of the aluminum from the system allows one to get a more accurate picture of the iron protection by the inhibitor. In the case shown in Table 4, the aluminum made no difference insofar as iron protection was concerned, but there have been many other cases where the reverse happened.

Safety Margin

One of the most desirable characteristics of a Diesel cooling system corrosion inhibitor is that it have a "safety" margin insofar as dosage is concerned. Although most non-chromate inhibitors are recommended for use at a minimum of 0.75 oz/gallon of treated water, the wide variance in treatment facilities over a railroad system may result in the cooling water being "under treated" from time to time. Most of the early non-chromates lacked a "safety margin" and met with much difficulty because of this. Table 5 compares flask test results for two typical treatments, both of which were recommended for use at 0.75 oz/gallon. These treatments are with Inhibitor "C" which has a "safety margin" and Inhibitor "D" which does not. It is evident that Inhibitor "C" would be the preferred material.

As stated earlier, the composition of the water available for cooling purposes may vary over a very wide range. Flask tests therefore were set up to evaluate Inhibitor "D" at different values of Total Dissolved Solids. These included (a) Chicago tap water (low dissolved solids), (b) the standard test water (14 grains per gallon TDS), (c) the standard test water with 30 grains per gallon of NaCl added instead of 10, and (d) the standard test water with 50 grains per gallon of NaCl added instead of 10. Results are shown in Table 6. The effect of increasing the TDS is especially marked in the case of aluminum, the corrosion rate of which increases rapidly. It is interesting to note that, with the exception of aluminum, the laboratory work with Inhibitor "D" indicates it is still effective in waters containing as high as 50 grains per gallon NaCl.

Soluble-Oil Inhibitor

One type of non-chromate corrosion inhibitor which has shown some promise for Diesel cooling systems is the so-called "soluble-oil" or "organic" type of inhibitor. This type of inhibitor, however, in contrast to the "boron-nitrite" type, suffers from its penchant for attacking rubber hose and gasketing. Table 7 gives flask test corrosion rates for Inhibitor "E," a commercially available "soluble-oil" type inhibitor and Inhibitor "C," a "boron-nitrite" formulation. Comparing Inhibitor "E" with the "boron-nitrite" type at the recommended dosage, it appears that while the aluminum protection was somewhat better, the other metals suffered increased attack. From the results at dosages above and below the normal level, it can be seen that concentration control is much more critical for Inhibitor "E." At times during the testing, a corrosion specimen appeared to have gained in weight, as is noted here. Visual inspection always indicated excellent protection. This gain in weight probably is due to a tightly adherent oxide film.

The effect of the "soluble-oil" treatment on samples of Diesel gaskets and radiator hose in contrast to that of the "boron-nitrite" type is shown in Figures 3 and 4. In all cases, the specimens were immersed in a recirculating test (180 F) for two weeks.

Results of comparing a number of different commercial inhibitors using the flask test are shown in Table 8. These inhibitors were all tested at the dosage recommended by their manufacturers for their use. Inhibitor "G" gives the best results. Inhibitor "L" is an example of a material which is poor for copper and brass although good for the other metals. H, J and K are very bad for aluminum, while K is also bad for cast iron, the metal which it was supposedly designed to protect. A comparison of the specimens used in these tests before they were cleaned for weighing is shown in Figure 5. The pictures bring out the corrosion even more vividly than do the calculated corrosion rates.

The adaptability of this type of testing to solutions containing anti-freeze materials is brought out in the next series of flask tests. In these tests a number of anti-freeze materials were

added to the "standard" test water in a 50/50 mixture, and the regular corrosion tests were then carried out. In Table 9, the effect of methanol on the testing is shown. It can be seen that the presence of methanol makes the test especially severe on cast iron. In the coupled test, it appears to serve as a sacrificial anode for the other metals. Adding a commercial corrosion Inhibitor "G" brings the corrosion down to acceptable proportions. This table also brings out the effect of the length of the test period. Comparing the seven and thirty day results, it can be seen that while the attack remains high for the cast iron through the longer period in the uninhibited test, addition of the corrosion inhibitor makes the corrosion rate over a longer period negligible.

Similar tests were carried out with ethylene glycol as well as commercial anti-freeze materials of this type. These commercial materials were stated to contain corrosion inhibitors, and therefore tests were conducted both in the absence and presence of Inhibitor "G." Test results are given in Table 10, as well as in Figure 6. It is of interest to note that while all the "inhibited" commercial anti-freeze materials show some protection for cast iron to a greater or lesser degree in comparison with uninhibited ethylene glycol, they all increase the attack on aluminum. Addition of the Inhibitor "G" in all cases lowered the corrosive attack on the metal specimens by a considerable amount.

Tests with Heat Transfer

In the recirculating test, the coolant was passed through a heated iron tube, to evaluate corrosion and scaling at heat transfer surfaces. Visual examination of these areas for scaling or increased corrosion proved to be very helpful in the development of a satisfactory corrosion inhibitor.

Field Results

Correlation of the laboratory testing with field results has been very good. The inhibitor developed as a result of this testing, Inhibitor "G," has proven to be very successful in combating corrosion in hundreds of Diesel engines when used at the dosages prescribed by the laboratory testing. There has been no harmful effect on rubber hose by the Inhibitor "G"; on the other hand soluble-oil type inhibitors have attacked rubber hose as predicted in the laboratory. Inhibitor "G" has proven to be successful in applications where anti-freeze was used. Effectiveness of the inhibitor has varied in relation to the concentration employed in a manner directly comparable with laboratory results.

Summary

The studies described in this paper illustrate that when a corrosive system as complex as that encountered in railroad Diesel cooling systems is to be studied in the laboratory, it is necessary to develop testing procedures which are flexible enough to include all the variables which affect corrosion. Evaluation of a corrosion inhibitor under only one specific set of test conditions may lead to erroneous conclusions insofar as the value of that inhibitor for wide spread field application is concerned. Therefore a basic test procedure was developed of such a nature that corrosive conditions could be varied over the ranges encountered in field application.

A simple flask test was chosen as the basic test. Conditions which were varied to give useful information included variations in water composition, inclusion of anti-freeze materials, use of both coupled and insulated specimens, and testing at inhibitor concentrations both above and below the recommended dosages. Also, test specimens of non-metallic materials and tests with heat transfer were useful to give a well-rounded picture of inhibitor performance.

From the results of these various tests, it can be seen that it is possible to develop an inhibitor of the boron-nitrite type which will satisfactorily meet the demands of the corrosion problem in the Diesel cooling system.

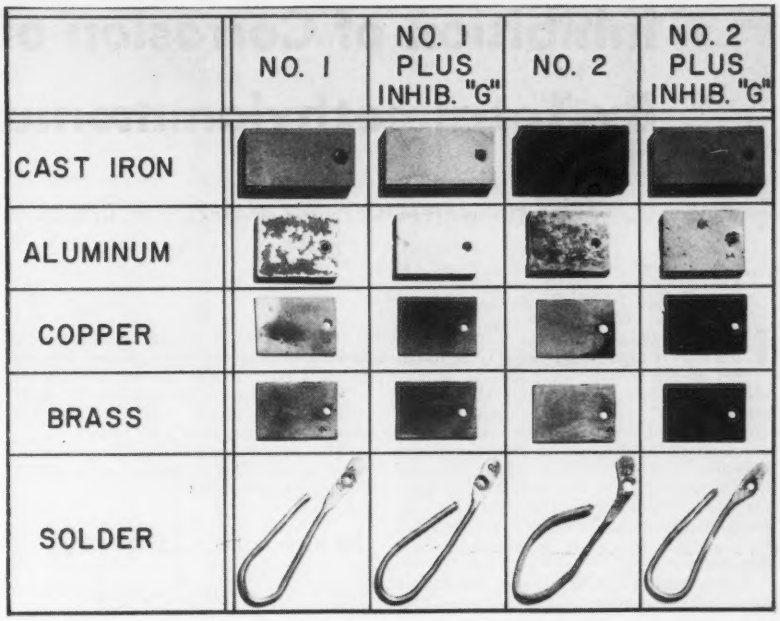


Figure 6—Corrosion tests with permanent anti-freeze (with coupled specimens). Corrosion rates are given in Table 10.

TABLE 10—Flask Tests With Glycol Antifreeze Materials*

Material	Type of Test	Corrosion Rates in mpy with Ethylene Glycol		Corrosion Rates in mpy with Commercial Antifreeze No 1		Corrosion Rates in mpy with Commercial Antifreeze No 2	
		No Inhibitor	Inhibitor "G" at 0.75 oz/gallon	No Inhibitor	Inhibitor "G" at 0.75 oz/gallon	No Inhibitor	Inhibitor "G" at 0.75 oz/gallon
Cast Iron	Coupled	16.9	2.4	6.3	0.2	3.5	0.2
Aluminum	Coupled	4.9	5.0	11.4	0.7	66.7	2.4
Solder	Coupled	0.7	2.5	0.7	1.0	0.5	0.7
Copper	Coupled	0.3	0.3	1.1	0.5	0.6	0.2
Brass	Coupled	0.6	0.2	0.7	0.2	0.5	0.1
Cast Iron	Insulated	7.9	2.1	4.3	0.3	9.6	0.3
Aluminum	Insulated	9.0	0.0	13.8	0.5	17.6	0.6
Radiator Tube	Insulated	0.5	0.1	0.1	0.0	0.7	0.1
Copper	Insulated	1.6	0.4	2.1	0.5	1.9	0.5
Brass	Insulated	1.9	0.4	0.8	0.3	1.5	0.2

* Seven Days at 180 F.

Acknowledgment

The authors are grateful to Dr. J. W. Ryznar, Jerome Green, Carl E. Johnson, L. S. Heason, R. G. Bielenberg and P. W. Evans for their advice and suggestions during the course of this work and to L. E. Hummel, T. R. Newman and J. A. Williams for their assistance in carrying out the experimental procedures.

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Any discussions of this article not published above will appear in the December, 1958 issue

Inhibition of Corrosion of Steel By Tetramethylammonium Bromide*

By RUDOLPH MACY,(1) B. L. HARRIS,(2) W. C. BULL(3) and J. W. EASTES(4)

Abstract

A review is made of work leading to the discovery that tetramethylammonium bromide (TMB) is an excellent inhibitor of corrosion of steel by bis (2-chloroethyl) sulfide. The nature of the corrosion problem involved is considered for both Levinstein H and distilled H. The search for a stabilizer for Levinstein H is described. Data are reported with no stabilizer, 1 percent hexamine stabilizer and 1 percent TMB stabilizer to show the rate of decomposition of Levinstein H in a 75 mm shell, rate of pressure developed in a 75-mm shell filled with Levinstein H, and rate of pressure development in 75-mm shell filled with distilled H. The rate of loss of liquid filling at 150 F with distilled H filled to 10 percent void in 75-mm shell is reported for no stabilizer, 1 percent hexamine and 0.5 percent TMB. 5.8.2

Introduction

IT HAS been found[1] that tetramethylammonium bromide, $(CH_3)_4NBr$, hereafter referred to as TMB, is an excellent inhibitor of corrosion of steel by mustard, bis(2-chloroethyl) sulfide, hereafter referred to by its chemical warfare symbol, H. A search of the literature indicates that stabilization of an organic liquid toward steel by means of a quaternary ammonium halide with an infinitesimally small solubility, rather than by a soluble amine, is apparently a new discovery.

In the preliminary review of the patent application, searchers in the Patent Office found that Endres[2] in his patent on the use of inorganic (and organic) azides as inhibitors for corrosion of steel by aqueous solutions described a mixture containing tetramethylammonium azide, $(CH_3)_4NN_3$. However, Endres does not refer to inhibition of corrosion by strictly non-aqueous systems. Patent Office investigators also pointed out that Mann et al[3] included tetramethylammonium hydroxide in their general study of amines as inhibitors of corrosion in pickling baths.

Nature of Corrosion Problem

Mustard can be made from thiodiglycol very simply by reaction with hydrochloric acid:[4,5]

$$(HOCH_2CH_2)_2S + 2HCl \rightarrow (ClCH_2CH_2)_2S + H_2O$$

Thiodiglycol (TG) — Mustard (H)

The purity of the H made by the TG process is generally better than 95 percent, and the corrosion effects of this H on steel are negligible.

The Levinstein process[5,6,7] is simpler from the standpoint of plant practice:

$CH_2 = CH_2$	S_2Cl_2
Ethylene	Sulfur monochloride
Reaction mixture	
H	HS_7
Mustard	Mustard polysulfides
Reaction product	

The product (containing about 30 percent of polysulfides from HS_2 to HS_7) is used as such. Crystalline sulfur slowly separates in storage at ordinary temperatures. Under tropic conditions (100 F to 125 F), however, Levinstein H rapidly attacks steel and at 150 F will dissolve thin test pieces in a few weeks.

The attack on steel by Levinstein H may be ascribed to oxidation by the sulfur of the polysulfides:

$$Fe + \ddot{S}: \longrightarrow Fe^{++} :\ddot{S}:^{=}$$

The initial reaction is followed by the formation of complex salts containing iron. During World War II it was found that the stability of Levinstein H toward steel could be improved by washing out with water the iron salts which may be present, followed by distillation under vacuum. This raises the purity from 70 percent to more than 90 percent.

It is known that corrosion of aluminum is inhibited by polysulfides.[8] This probably explains the stable behavior of aluminum to Levinstein H.

Since Levinstein H at surveillance temperatures (120 F to 170 F) is essentially a solvent for steel, the rate of corrosion of steel is highly dependent on the surface-volume ratio, that is, the ratio of the area of the wetted surface to the volume of liquid. This ratio is high in a small container like a 75-mm shell and correspondingly low in a storage container like the 55-gallon drum. The corrosion rates fall off rapidly with decreasing surface-volume ratios, but such data will not be presented here. Curve A in Figure 1 shows the rate of decomposition of Levinstein H in a 75-mm shell at 150 F, when unstabilized. The liquid phase may contain up to about 20 percent iron, calculated as ferrous chloride.

Although the distilled H is not a solvent for steel at the elevated temperatures, it still poses an unusual corrosion problem. As shown in Curve A of Figure 2, at the end of the storage period about 15 to 20 percent of the liquid phase has disappeared (as compared with a drop in purity of about 10 percent). The lost liquid is contained in a crust uniformly deposited on the shell wall. The crust can be removed easily with water, and analysis of the water solution indicates that the corrosion process involves the loss of about 6 grams of H for each gram of iron supplied by the shell. The crust has the dubious beneficial effect of stopping further corrosion when it reaches a certain thickness. As a rule, less than 1 percent of iron (as ferrous chloride) is found in solution in the liquid mustard phase.

Under equivalent conditions the pressures developed at 150 F by distilled H (Figure 3) are higher than those by Levinstein H (Figure 4). There is a longer induction period for the distilled H, but the pressure then rises more rapidly and reaches a somewhat greater maximum. However, distilled H does not develop pressure at all at 150 F in

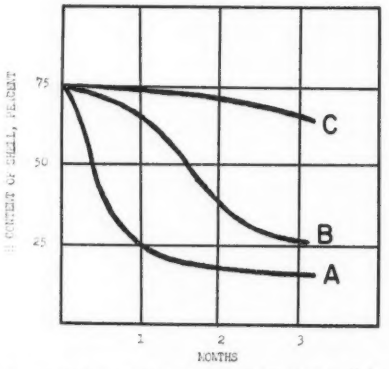

Figure 1—Rate of decomposition of Levinstein H in 75-mm shell filled to 10 percent void and stored at 150 F. Code to curves is as follows: A—no stabilizer; B—stabilized with 1 percent of hexamine; C—stabilized with 1 percent of TMB.

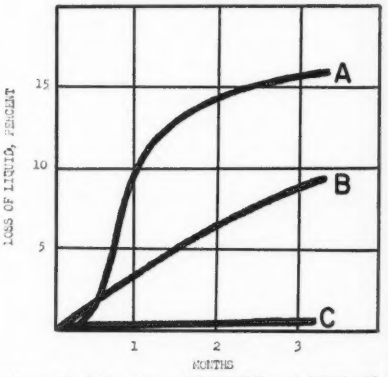

Figure 2—Rate of loss of liquid filling at 150 F with distilled H filled to 10 percent void in 75-mm shell. Loss is due to crust formation. Code to curves is as follows: A—no stabilizer; B—stabilized with 1 percent of hexamine; C—stabilized with 0.5 percent of TMB

* Submitted for publication June 18, 1957. This paper is essentially the same as the one entitled "Stabilization of Mustard by Tetramethylammonium Bromide" which was presented at the April 1957 meeting of the American Chemical Society held in Miami.

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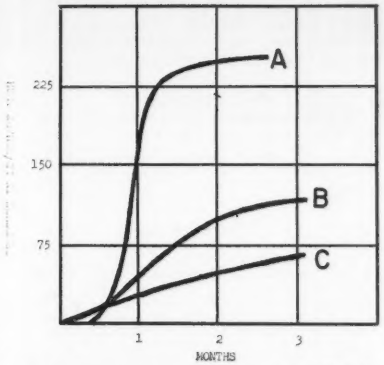


Figure 3—Rate of pressure development at 150 F in 75-mm shell filled with distilled H to 10 percent void. Code to curves is as follows: A—no stabilizer; B—stabilized with 1 percent of hexamine; C—stabilized with 1 percent of TMB.

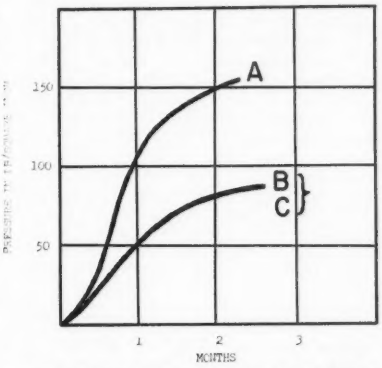


Figure 4—Rate of pressure development at 150 F in 75-mm shell filled with Levinstein H to 10 percent void. Code to curves is as follows: A—no stabilizer; B—stabilized with 1 percent of hexamine; C—stabilized with 1 percent of TMB.

an all-glass apparatus (Figure 5) similar to that described by Bellinger et al,[9] whereas Levinstein H in glass develops small pressures due to decomposition of small concentrations of over-chlorinated compounds[6] which it contains. The pressure in all cases is due principally to hydrogen.

Search for Stabilizer

Intensive work on the stabilization problem was started in 1943. Early tests were run in steel test cups with a capacity of about 50 cc of liquid, but the screening of a large number of inhibitors was later done in a glass apparatus (Figure 5) with a mercury manometer. The capacity of the glass apparatus was about 5 cc. Steel test strips, not completely covered by the liquid, were used in this apparatus to give a liquid-to-surface ratio approximating that in a 75-mm shell. The final tests were run in the 75-mm shell, and the procedure using the apparatus in Figure 5 was largely abandoned when it was found that inhibitors which seemed satisfactory in those tests failed when tested in the munition.

The 75-mm chemical shell held about 350 cc at 10 percent void, with the central burster tube in position. The shell was filled through a ¼-inch hole tapped in the bottom, and it was stored nose down with a pressure gage screwed into the ¼-inch hole (Figures 6 and 7).

Inhibitors were chosen somewhat at

Figure 5—Glass apparatus (with 1-cm mercury slug) to measure pressure development.

random for test. The initial experiments were guided, however, by the fact that amines are known to be good stabilizers for compounds which tend to be catalytically decomposed by hydrochloric acid, and by the fact that ammonia had been favorably reported[10] as a stabilizer for Levinstein H as well as a precipitating agent for the "excess" sulfur from the polysulfides. Among the many amines which were tested was acetaldehyde ammonia, the product of the reaction between ammonia and acetaldehyde. This amine gave poor results although it was thought that it might liberate ammonia slowly and thus exert some inhibiting action. This led to a test with hexamine, hexamethylenetetramine, $(CH_2)_6N_4$, the product of the reaction of ammonia with formaldehyde.

The tests with hexamine were started at Army Chemical Center using a maximum of 0.5 percent of the compound. While these tests were running, a group at the CWS Development Laboratory of the Massachusetts Institute of Technology started experiments using 1 percent of hexamine in test tube samples containing steel strips. The latter workers reported excellent results,[11] and because of the urgency of the situation with regard to Levinstein H, this concentration of hexamine was adopted as a stabilizer. The use of 0.5 percent of hexamine at Army Chemical Center had been found to give only fair results, and even at the concentration of 1 percent hexamine was eventually found to be none too satisfactory as a stabilizer when tested in shell. Hexamine was more satisfactory for inhibiting pressure development (Figures 1 and 4) than as an inhibitor for chemical decomposition.

The addition of hexamine to H yields a voluminous precipitate. The crystals obtained from a mixture of 1 percent of hexamine in H of 99.5 percent purity gave an analysis intermediate between the complexes represented by 1 Hex:1 H and 2 Hex:1 H. These are salts formed by the quaternization of one or two

Figure 6—Chemical shell (75-mm) nose down as used in storage tests.

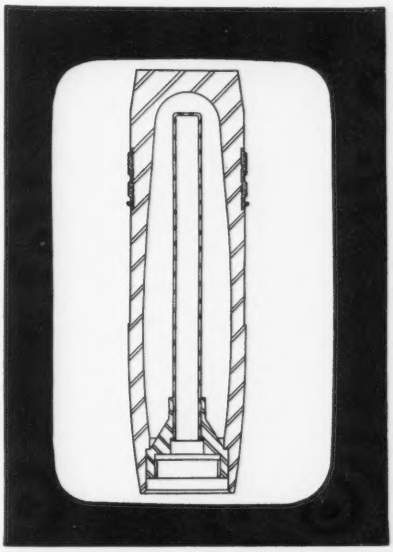
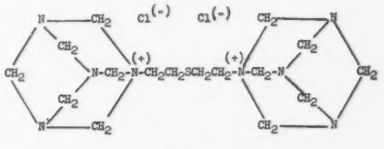


Figure 7—Chemical shell (75-mm) in outline, shown with burster tube in place.

hexamine molecules by a molecule of mustard. In the formula below, the bis-quaternary compound is shown.



It was postulated that stabilizing activity was due to the presence of these ammonium-type compounds rather than to the hexamine itself. About 20 amine salts and quaternary ammonium salts were obtained and tested, and the search was rewarded by the discovery of TMB as an inhibitor. The relative activities of TMB and of hexamine are shown in

TABLE 1—Pressure Developed at 150 F in Presence of 0.5 Percent Stabilizer*

Subtance	Days	PRESSURE IN ATMOSPHERES WITH STABILIZERS INDICATED							
		None	Hex	Hex·HCl	Hex·EtI	Me_4NCl	Me_4NBr	Me_4NI	Et_4NBr
Distilled Mustard..	5	—0.06	—0.12	—0.16	—0.06	—0.10	—0.14	—0.15	—0.16
Distilled Mustard..	30	0.2	—0.06	—0.10	0	—0.06	—0.10	—0.04	1.0
Distilled Mustard..	60	2.3	0.2	—0.06	0.06	0.06	—0.04	0.30	2.4
Distilled Mustard..	90	3.4	0.3	—0.04	1.40	0.16	0	0.56	2.8
Levinstein Mustard.	5	0	—0.12	—0.10	—0.12	—0.16	—0.16	0	—0.10
Levinstein Mustard.	30	1.6	0	0.06	0.8	0.50	0.25	2.0	0.62
Levinstein Mustard.	60	2.1	0.4	0.38	5.0	1.0	0.80	High	1.35
Levinstein Mustard.	90	2.4	0.6	0.56	High	1.4	1.3	....	1.75

NOTE: Hex = hexamine; Me = methyl; Et = ethyl; None = no stabilizer added

*Tests were made using glass apparatus with steel strip and 35 percent void space.

Figures 1 through 4. TMB is far superior to hexamine with respect to inhibition of chemical decomposition, but with respect to pressure development the superiority is not so marked. The solubility of TMB in H is infinitesimally small, an attempt to determine the amine function by analysis, for example, indicating that the solubility is below 0.01 percent. The work was done with TMB of which the crystal size resembled that of ordinary table salt. It is quite possible that smaller concentrations than 1 percent would be effective for inhibition if the TMB were micropulverized, to provide a larger surface.

Representative results shown in Table 1 were obtained when the amine salts and quaternary ammonium salts were tested primarily with respect to pressure inhibition in the apparatus shown in Figure 5. Hexamine hydrochloride appeared to be quite promising in these screening experiments, but when tested in the 75-mm shell the results were practically the same as those for hexamine itself as shown in Figures 1 to 4. As stated earlier in this paper, these preliminary tests were not always supported by the tests in a steel container.

Acknowledgment

Grateful acknowledgment is made to the numerous personnel who assisted in this work, with special thanks to T. B. Stackpole, P. B. Coulter, and C. E. Miller.

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Any discussions of this article not published above will appear in the December, 1958 issue

Inhibition of Titanium In Fuming Nitric Acid*

By J. B. RITTENHOUSE and C. A. PAPP

Abstract

Storage tests were conducted to determine the effectiveness of oxygen in inhibiting the corrosion reaction of titanium in fuming nitric acid (FNA). In these tests, which were of 28 days duration at a temperature of 30 C, the samples investigated were ½-inch squares (0.020 inch thick) of commercially pure titanium (75A) and a binary 8 percent-manganese alloy (C110M). The specimens were stored in Teflon-lined aluminum pressure vessels at 50 percent ullage. The pressure vessels were of the following types: vented to the atmosphere, sealed with air in the vapor space, sealed with oxygen atmosphere in the vapor space, and equipped for a 1-ml/minute oxygen flow through the vapor space. Results of the investigation indicated no inhibition of titanium corrosion by oxygen, but confirmed the inhibiting effect of a water content of 1 to 2 percent by weight in the FNA. 4.3.2

Introduction

RECENT STUDIES[1] have indicated that the corrosion reactions of titanium and its alloys in fuming nitric acid (FNA) can be inhibited by a water content of 1 to 2 percent in FNA containing 0 to 20 percent NO_2. Addition of the water alleviates the tendency of the material, when exposed to anhydrous FNA, toward ignition reactions and stress cracking. Interest in this work has been exhibited recently by titanium producers and users concerned with the application of titanium and its alloys to certain rocket systems where FNA is used as an oxidizer.

Bomberger[2] performed experiments which seemd to indicate that inhibition could be affected by the presence of oxygen. It should be noted, however, that he did not report chemical analyses of the acids used either before or after the corrosion process. In view of the fact that experiments by many workers[1, 3] have shown that the water and NO_2 content of FNA are the critical parameters defining the corrosion, pyrophoricity, and stress corrosion cracking of titanium, the work described in the present paper was performed under controlled conditions. The tests were designed to show that oxygen is not the inhibiting agent decreasing corrosion of titanium and that the apparent inhibition observed by Bomberger had its origin in the changing composition of the FNA with a resulting increase in the water content to approximately 1.5 percent.

Experimental Procedure

Steps were taken to eliminate metal impurities in the FNA used in the experiments at this laboratory, and to ensure prior knowledge of the initial acid compositions. This was accomplished by blending laboratory-prepared fuming nitric acid from purified nitrogen dioxide, distilled water, and pure nitric acid obtained as the vacuum distillate of the reaction product of reagent-grade sulfuric acid and potassium nitrate. The pure nitric acid and nitrogen dioxide were stored under refrigeration at —30 C in order to obviate thermal decomposition prior to the blending procedure.

Chemical analyses of the FNA were performed before and after the corrosion tests. The total acidity of the mixture was determined by titration with NaOH. The NO_2 concentration was ascertained by ceric sulfate titration. The concentration of H_2O was found by a modified Karl Fischer procedure developed at this laboratory. Metals in solution were determined by colorimetric procedures.

The materials used for the specimens were the commercially pure titanium 75A and the binary 8 percent-manganese alloy C110M sheared in ½-inch squares from sheets 0.020 inch thick. Thus, the ratio of the total area of the metal to the FNA liquid volume was 1.2 $inch^{-1}$. The sheared pieces of metal were stress-relieved under vacuum in sealed Vycor ampoules by heating them for two hours to the annealing temperature appropriate for the material involved; the heating period was followed by slow cooling in the furnace. The total area of each sample was carefully measured, and, immediately prior to storage in the pressure vessel, each sample was sandblasted and weighed (to provide a basis for weight-loss determinations).

Teflon-lined aluminum-alloy pressure vessels 5 inches deep and with 1-inch inside diameters were used for the storage tests. The vessels were filled to 50 percent ullage, and the titanium specimens were positioned in either the liquid or the vapor phase of the FNA by supporting them on Teflon rods.

In order to provide variations in the storage conditions, the pressure vessels were equipped in four different ways. Some of the vessels were vented to the atmosphere. In some, provisions were made for flowing oxygen through the vapor space above the FNA by means of ⅛-inch-diameter aluminum tubing attached to the vessel closure through pressure fittings. The oil-pumped oxygen was dried by passing it through Drierite; the flow rate of the dried oxygen through a calibrated rotameter was 1 ml/minute. Some of the vessels were sealed and contained FNA under an atmosphere of oxygen. Other sealed vessels contained air in the ullage space. Teflon gaskets in the pressure-vessel cover prevented contact of the liquid FNA with the aluminum of the vessel cover and tubing. All pressure vessels were stored in a constant-temperature water bath, controlled by means of a mercury regulator to a temperature of 30 C ± 1 C.

Experimental Results

In Reference 2 it was indicated that titanium corrosion rates were larger in a sealed container and were lower when the flask was open to the atmosphere or when oxygen was periodically allowed to flow through the vapor space above the FNA. It will now be shown that this decrease in corrosion rates attributed to inhibition by absorbed oxygen was actually caused by the decrease in NO_2 concentration and increase in water content in the FNA resulting from corrosion, thermal decomposition of the acid, loss of volatile NO_2, and increase in water content of the FNA.

The initial and final analyses of the acids used are shown in Table 1, together with the storage conditions and

Papp

Rittenhouse

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TABLE 1—Storage Tests of Titanium Alloys in FNA at 30 C for 28 Days

Test No.	Ti Alloy	Storage Condition	FNA Analysis: Original Concentration (Wt. Percent) NO_2	FNA Analysis: Original Concentration (Wt. Percent) H_2O	FNA Analysis: Final Concentration (Wt. Percent) NO_2	FNA Analysis: Final Concentration (Wt. Percent) H_2O	Average Corrosion Rate (Mils/Year) In Liquid	Average Corrosion Rate (Mils/Year) In Vapor	Metal in Solution (Wt./Percent) Ti	Metal in Solution (Wt./Percent) Mn
16	75A	Vented	19.5	0	19.94	0.78	2.42	1.42	0.15	—
9	75A	1 atm O_2	19.5	0	20.03	0.18	2.05	1.17	0.05	—
1[a]	75A	O_2 flow	18.7	0	11.67	0.52	1.51	0.47	0.03	—
19	75A	Sealed	19.5	0	20.04	0.15	2.15	1.55	0.08	—
14	75A	Sealed	20.7	1.4	20.56	2.07	0.13	0.12	<0.01	—
141	75A	Sealed	11.9	0.4	11.96	0.58	<0.01	<0.01	—	—
22	Control	Sealed	19.5	0	19.81	0.53	—	—	—	—
18	Control	Vented	19.5	0	19.58	0.15	—	—	—	—
21	Control	Sealed	20.7	1.4	20.59	1.72	—	—	—	—
15	C110M	Vented	19.5	0	22.21	0.43	49.5	14.5	0.88	0.13
11	C110M	1 atm O_2	19.5	0	22.43	1.40	51.5	9.9	0.83	0.13
2[a]	C110M	O_2 flow	18.7	0	11.99	1.47	24.3	0.28	0.40	0.06
20	C110M	Sealed	19.5	0	22.32	1.35	50.8	9.5	0.81	0.12
17	C110M	Sealed	20.7	1.4	20.68	2.31	1.57	1.40	0.03	—
171	C110M	Sealed	12.3	1.5	12.45	1.27	2.95	1.80	0.07	<0.01

[a] Final volume of FNA approximately 2/3 of original volume.

the corrosion rates determined. In tests 1 and 2 (in which oxygen was flowing through the system), the volume of the acid was reduced to approximately 66 percent of the original volume during the 28-day storage period. This reduction in volume was caused by the removal of the volatile reaction products H_2O, O_2, NO_2, and HNO_3 resulting from the thermal decomposition and corrosion reactions of the acid.[4] The O_2 is virtually insoluble in FNA, whereas the HNO_3 and NO_2 exert some vapor pressure; therefore, these species were removed by the oxygen which was passed through the system. The experimental evidence shows that the NO_2 concentration in tests 1 and 2 was reduced to approximately 60 percent of the initial value.

Correspondingly, the corrosion rate for 75A material shown in the data for test 1 was about 70 percent of the average of the rates found for this metal after storage in anhydrous FNA (19.5 percent NO_2) in either sealed or vented vessels (see Table 1, tests 9, 16, and 19). On the other hand, as shown in test 2, the corrosion rate for C110M material was about 50 percent of the average of the rates found for this alloy (tests 11, 15, and 20) after storage in anhydrous FNA (19.5 percent NO_2). It is obvious that the decrease in the NO_2 concentration of the FNA when O_2 was passed through the system was comparable with the decrease in the corrosion rates of the titanium alloys. It can be concluded, therefore, that the decrease in corrosion rates was a result of the change in the FNA concentration, and not a result of inhibition of the metal-FNA reaction by oxygen.

In test 20 (a sealed system, 0 percent H_2O) the corrosion rate was 50.8 mils/year, whereas in test 17 (sealed with 1.5 percent H_2O) the rate was 1.57 mils/year. The average of the rates of these two tests was approximately 26 mils/year, whereas the corrosion rate in test 2 was 24 mils/year. These values are comparable and demonstrate that the rate found for the system in which oxygen flowed through the vapor space is an arithmetic average of the rates for sealed containers containing 0 percent H_2O and 1.5 percent H_2O, respectively (with approximately 20 percent NO_2). It is significant that the final H_2O concentration in the flowing-oxygen test for the C110M material (test 2) was 1.5 percent.

In tests 141 and 171 (Table 1) the 75A and the C110M samples were stored in sealed containers with FNA having an initial composition comparable to the final FNA compositions in tests 1 and 2. The corrosion rates obtained in FNA of this initial composition were very low. This behavior confirms the observation that the decomposition of the FNA in tests 1 and 2 contributed to the reduced corrosion rates found in these tests. It further confirms the fact that at a fixed NO_2 concentration, H_2O is the FNA constituent chiefly contributing to the reduction of the titanium-corrosion rates. None of the samples in tests 141 and 171 exhibited pyrophoric reactions after storage.

In all the other experimental tests, the NO_2 concentration increased. This increase was due either to thermal decomposition of the FNA or to corrosion; both of these reactions[4] cause an increase in NO_2. This fact can be seen in the equation for the thermal decomposition of nitric acid and in the equation for the corrosion reaction between nitric acid and a metal M of valence n:

$$4HNO_3 \rightleftarrows 4NO_2 + 2H_2O + O_2 \quad (1)$$

$$M + 2nHNO_3 \rightarrow nNO_2 + nH_2O + M(NO_3)n \quad (2)$$

Water also is a product of the thermal-decomposition and corrosion reactions (see Equations 1 and 2); in Table 1, in general, the H_2O concentration was increased at the end of the 28-day storage period. A hydrogen balance of the species in solution in the FNA after storage was calculated, in which either the thermal-decomposition or the corrosion reaction was considered, and it was found that the amount of HNO_3 reacted was between 5 and 15 percent.

In Table 1, it can be seen that the titanium-to-manganese ratio of the metal found in solution in the FNA after storage of the C110M alloy was, on the average, 6:1. This behavior is comparable to the findings presented previously[1] where the ratio of titanium to manganese was approximately 5:1. It should be noted that the titanium-to-manganese ratio in the alloy is approximately 13:1. This behavior indicates preferential solution by FNA of manganese-rich phases of the alloy.

In tests 14 and 17 (Table 1), in which the FNA (20.7 percent NO_2) initially contained approximately 1.5 percent H_2O, the corrosion rates were low. This behavior confirms the previous findings of this laboratory and other research organizations[2] concerning the inhibiting effect of a water content in the range 1 to 2 percent on the corrosion rates of titanium alloys in FNA. For the 75A metal, the effect of the addition of 1.5 percent H_2O to FNA containing approximately 20 percent NO_2 was to decrease the average corrosion rate by a factor of 17 when compared with tests 9, 16 and 19; for the C110M alloy, the addition of H_2O to the FNA decreased the average corrosion rate by a factor of 32 when compared with tests 11, 15 and 20.

The experiments of Reference 2 seemed to indicate that the corrosion rates were larger in a sealed system than in a vented system. This behavior was attributed to the inhibiting effect of oxygen adsorbed on the liquid-titanium interface, for in a system open to the atmosphere, more oxygen is available for adsorption on the alloy surface.

As shown in Table 1, the pressure vessels used in tests 15 and 16 were vented to the atmosphere, whereas in tests 19 and 20 the vessels were sealed with air in the vapor space, and in tests 9 and 11 the vessels were sealed with an atmosphere of oxygen in the vapor space. The corrosion rates for the 75A titanium in the three tests 9, 16, and 19 (Table 1) are comparable. The deviations of the rates from the average of the three are 7, 9.5, and 3 percent, respectively. Similarly, for the C110M titanium alloy, the deviations of the three tests 11, 15, and 20 (Table 1) from the average corrosion rate of the three are 1.8, 2.2, and 0.4 percent, respectively. It would appear from these results that, within the limits of error of the corrosion-rate measurement, oxygen has little inhibiting effect upon the corrosion of titanium alloys in FNA (20 percent NO_2, 0 percent H_2O).

Conclusions

The inhibiting effect of water concentration in the range 1 to 2 percent in FNA (20 percent NO_2) on the corrosion rates and pyrophoric reactions of titanium alloys as reported previously[1] was confirmed in the present 28-day storage tests at 30 C. In this present investigation, oxygen, either sealed in the system or absorbed from the atmosphere, showed no inhibiting effect upon these reactions.

The corrosion rates of titanium in sealed or vented pressure vessels were virtually identical in anhydrous FNA containing 20 percent NO_2. The metal after corrosion in anhydrous RFNA (20 percent NO_2) was pyrophoric whether sealed with air in the vapor space, sealed with oxygen in the vapor space, or vented to the atmosphere.

Acknowledgment

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Laboratory Studies Relating Mineral Quality of Water To Corrosion of Steel and Cast Iron*

By T. E. LARSON and R. V. SKOLD

Abstract

The influence of combinations of various normal mineral components in domestic waters on the rate of corrosion of cast iron and steel and on the development of tuberculation is reported. Tests were conducted with air saturated waters at room temperature with velocities of 0.1-1.0 fps and with pH controlled by carbon dioxide. The ions considered are chloride, sulfate, bicarbonate and calcium at pH 6.8-8.3. 4.6.6

Introduction

A STUDY of the effects of methods of water purification on loss in carrying capacity of water mains was begun in 1954 by the Illinois State Water Survey. Such a study was important in view of the fact that carrying capacity of water mains can be greatly reduced by obstructions to flow of water.

Obstructions in water mains may be due to: (1) the accumulation of debris, such as settled turbidity or suspended matter, (2) biological slimes or growths on the pipe walls, (3) after-precipitation of minerals left in a supersaturated state from the treatment, or (4) tuberculation i.e., growths or the accumulation of corrosion products on the pipe wall.)

A major concern in this study of treatment methods has been to determine modifications in water quality which may cause or prevent tuberculation. Since tuberculation is a by-product of corrosion, laboratory studies were devoted to the study of mineral quality of water as related to corrosion. The type of water studied approximates the quality of Great Lakes waters.

Steel

The accelerative effect of chlorides and sulfates in causing corrosion is well known. Previous studies[1] by the Water Survey also have indicated that, even in the absence of calcium, bicarbonates inhibit the corrosion of steel. Furthermore, the proportion of the naturally occurring bicarbonate inhibitor to the chloride and sulfate in domestic waters appears to be a fundamental factor in the corrosivity of waters at pH 7 to 8 (Figure 1.)

It was found that in chloride/alkalinity ratios of 0.2 to 0.4, the specimens were very sensitive to other alterations in quality. The presence of free chlorine was found to increase the corrosion rate of steel at chloride/alkalinity ratios of 0.2 to 0.3 (Figure 2).

A method of determining the instantaneous corrosion rate[2] of specimens was developed. This method consists of determining the polarization which occurs at extremely low magnitudes of current density and of empirically relating this parameter to weight loss determinations. The authors have been extremely gratified to see the academic confirmation of this relationship by Stern[3] in recent publications.

It should be mentioned also that these data were obtained with specimens totally immersed in 18 liters of prepared solutions, saturated with air at room temperature and with CO_2 used to control pH. The apparatus[4] provided a constant velocity of the specimens in a vertical circular path. Velocities above 0.9 fps were not used. The effect of pH on corrosion (or lack of corrosion) of steel by bicarbonate waters in the absence of calcium was also determined[2] (Figure 3). This effect was found to be contrary to the previously accepted concept[5] of the effect of pH. The point to be emphasized is that these data apply only to water of specific quality tested and to the conditions of the test. If the corrosive environment is altered, another relationship may occur.

Figure 4 shows results of a more recent test with a water having a much higher chloride content than that shown in Figure 3. The general trend of the data in both of these figures is similar; however, the corrosion rates in water having high chloride content are considerably higher than those in water of low chloride content. Both of these tests were conducted at low velocities.

Larson Skold

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RONALD V. SKOLD—Research Associate, Illinois State Water Survey, Urbana, Illinois. Since 1954 he has been engaged in research studies of the corrosion of water distribution lines. Mr. Skold received a BS in chemical engineering from the University of Illinois in 1949. From 1949 to 1952 he was employed at Mellon Institute where he did research in the field of adsorption. From 1952 to 1954 he was with Dearborn Chemical Company and Aquamatic Inc., where he specialized in applications of ion exchange.

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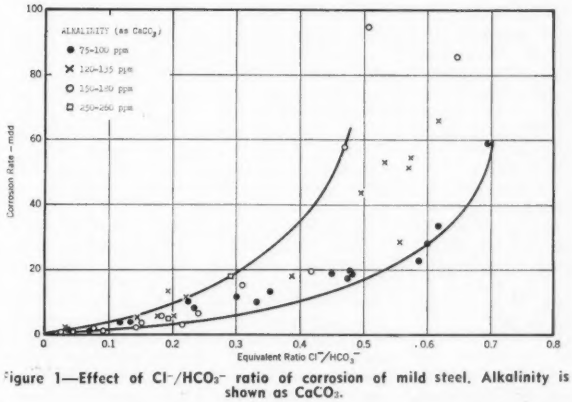

Figure 1—Effect of Cl^-/HCO_3^- ratio of corrosion of mild steel. Alkalinity is shown as $CaCO_3$.

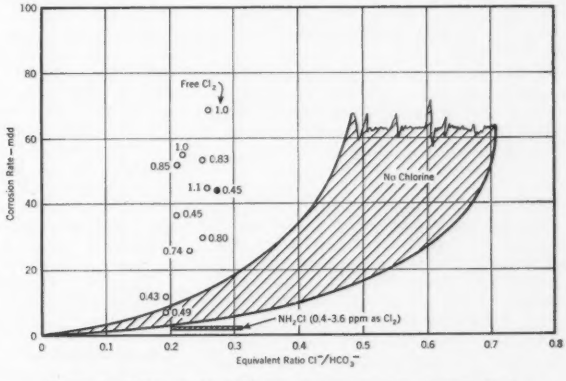

Figure 2—Effect of Cl^-/HCO_3^- ratio on corrosion of mild steel.

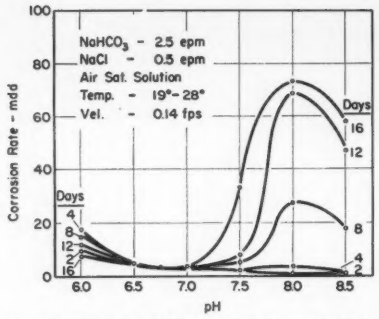

Figure 3—Effect of pH on corrosion rate of steel with $Cl^-/HCO^-_3 = 0.2$

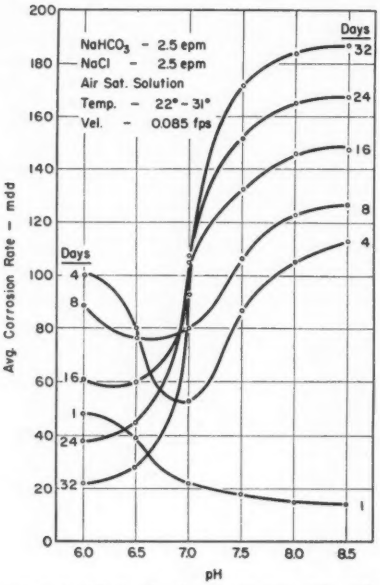

Figure 4—Effect of pH on corrosion rate with $Cl^-/HCO^-_3 = 1.0$

For this particular pair of graphs, it also should be recognized that the alkalinity was constant at all values of pH. The Whitman, Russell and Altieri[5] data were obtained with different concentrations of alkalinity and chloride at each pH. Figure 5 shows the type of corrosion products adhering to the steel specimens used to obtain the data in Figure 4. These pictures were taken at the end of the test (35 days), and the corrosion rates shown were final measured rates. It is interesting to note the increasing degree of tuberculation as the pH increases.

In the presence of calcium, as might be expected, the corrosion of steel decreased with increasing calcium concentration or with increasing pH at a chloride/alkalinity ratio of 0.4.

Cast Iron

The susceptibility of cast iron to corrosion is unlike steel. Cast iron contains graphite in a matrix of ferrite or pearlite and therefore is susceptible to initial galvanic corrosion at each graphite exposure which occurs at approximately 0.04 mm intervals.

Modern production of cast iron pipe produces an outside surface primarily of iron oxide which serves as an excellent barrier to atmospheric corrosion.

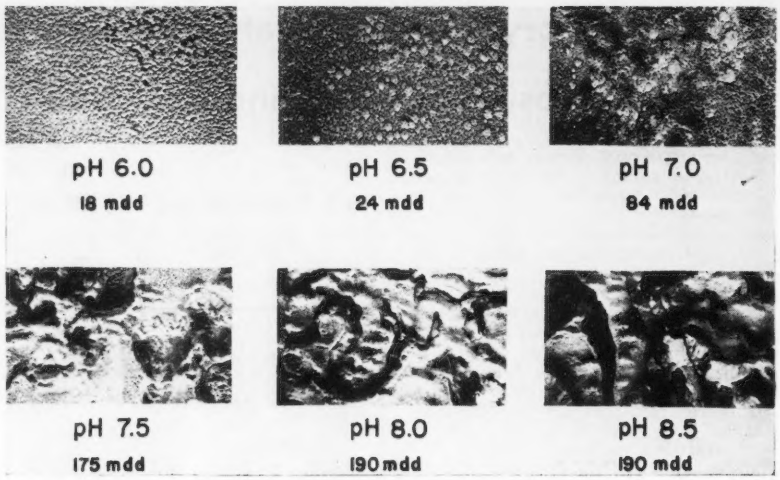

Figure 5—Corrosion products on steel specimens used to obtain data given in Figure 4. Samples shown are actual size.

Also, the inside surface is found to be highly resistant to corrosion by water, but when this surface is machined or ground, the resistance disappears. In the absence of calcium or large concentrations of corrosion inhibitors, each quality of water tested was found to cause corrosion of ground-surface cast iron.

Grinding of Cast Iron Pipe Interiors

It was learned, from personal plant inspection and correspondence, that the interior of all centrifugally cast pipe is partially ground for the purpose of reducing roughness prior to the application of coal tar coating or cement lining. In this process, most cast iron pipe interiors are ground to the extent of 10 to 50 percent of the surface.

Because most cast iron pipe in service is tar coated, it appears that tuberculation in such pipe results from slight but significant corrosive action of partially inhibited water on holidays, or minute holes, that occur in the tar coating covering the machined areas.

To determine the composition on the interior "skin" of the non-ground pipe surface responsibile for the remarkable corrosion resistance, a specimen was submitted to Professor W. H. Bruckner of the University of Illinois Department of Metallurgy. Figure 6 shows a microphotograph of an unetched mount.

When the "skin" on the internal surface of the pipe was scraped, the black phase between the metal surface and the gray phase was found to be ferromagnetic (Fe_3O_4) with a cubic structure.

The gray phase on the exposed surface, adjacent primarily to the magnetite, showed two or more components under polarized light: long needle-like pyroxenes of monoclinic structure as $CaSiO_3$ or $FeSiO_3$ (Mg or Mn); and polyhedron garnet of cubic structure, such as $Ca_3Al_2(SiO_4)_2$ or $Fe_3Al_2(SiO_4)_2$.

It appears that this silicate "skin", which is highly insoluble, may provide an effective barrier to corrosion by water. It is very brittle and therefore is not a completely effective barrier.

Further studies[6] were devoted to ground-surface specimens of cast iron in waters containing calcium.

Concentration of Calcium

A broad generalization of these data indicates (Figure 7) that the *concentration* of calcium in the presence of alkalinity is a primary factor in the inhibition of corrosion of machined cast iron. This generalization appears to be evident irrespective of the saturation index for $CaCO_3$ solubility, of velocities from 0.085 to 0.85 fps, of minor variations in chloride/alkalinity ratio, or of the presence or absence of chlorine, chloramine, or silica. It also appears that the specimens must be exposed a certain length of time at these velocities before the inhibition occurs.

Figure 6—Microphotograph of an unetched mount of cast iron pipe showing the non-ground pipe surface. Original magnification, 100X; actual magnification after reduction for engraving purposes, 26X.

In this generalization, representing all tests, there are broad variations in rates of corrosion (as much as tenfold for each level of calcium.) These variations will be indicated for specific modifications in water quality, first at the 125 ppm calcium hardness level. The data are represented as smooth lines from the average rates, determined five times per week for triplicate specimens.

Figure 8 shows the reduction in corrosion rates with time for three degrees of saturation with respect to calcium carbonate at a low velocity of 0.085 fps. The decrease in rate of corrosion occurred most rapidly in water at —0.1 saturation index and least rapidly at —0.8 saturation index.

The specimens in water at —0.3 saturation index leveled off at a higher final corrosion rate than either of the other two previously mentioned. It should be indicated that the specimens at this saturation index showed small dark reddish spots or growths surrounded by an over-all whitish red deposit, even prior to the addition of chlorine, and these spots continued to form tubercles. Simi-

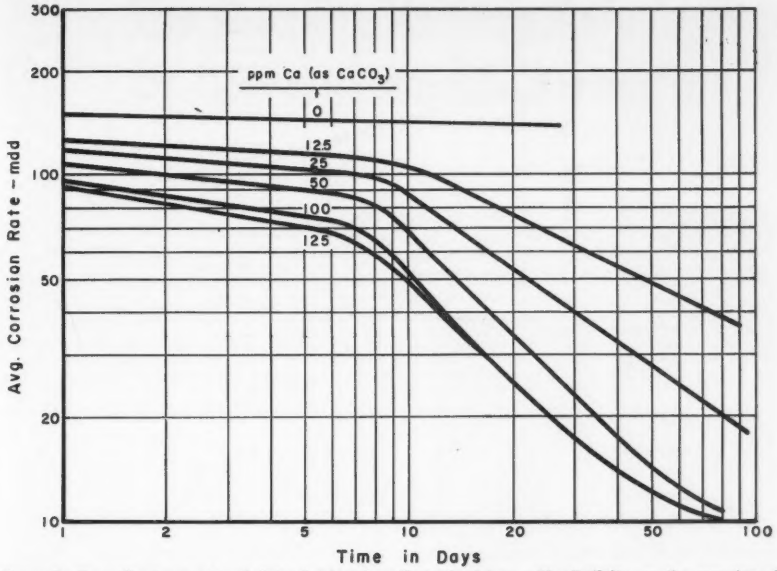

Figure 7—Generalized summary of data showing the effect of calcium, with alkalinity, on the corrosion of machined cast iron. Alkalinity was 125 ppm (as $CaCO_3$) and velocity range was 0.08 — 0.85 fps. Tests were made at room temperature.

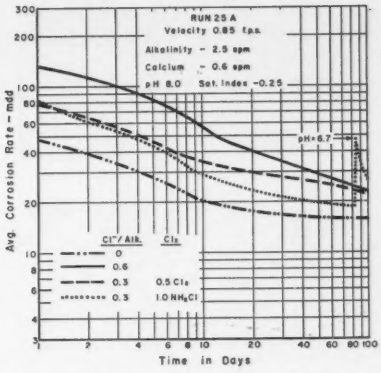

Figure 10—Corrosion rate varaition with time for machined cast iron at 0.85 fps.

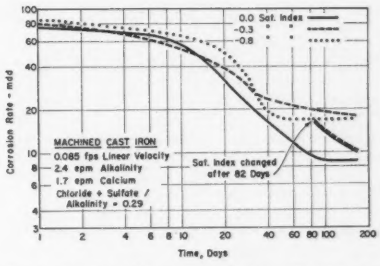

Figure 11—Corrosion rate variation with time for machined cast iron at 0.085 fps.

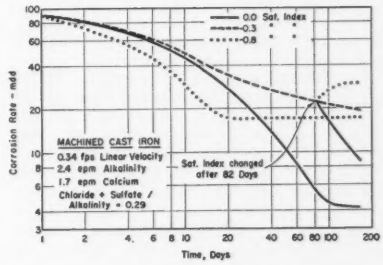

Figure 12—Corrosion rate variation with time for machined cast iron at 0.34 fps.

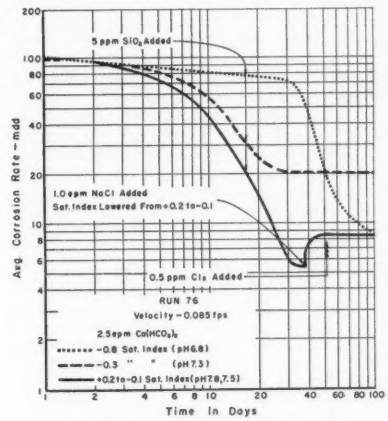
5 ppm SiO2 Added
1.0 epm NaCl Added
Sat. Index Lowered From +0.2 to -0.1
0.5 ppm Cl2 Added
RUN 76
Velocity - 0.085 fps
2.5 epm Ca(HCO3)2
-0.8 Sat. Index (pH 6.8)
-0.3 " " (pH 7.3)
+0.2 to -0.1 Sat. Index (pH 7.8, 7.5)
Avg. Corrosion Rate - mdd
Time In Days

Figure 8—Corrosion rate variation with time for machined cast iron at 0.085 fps.

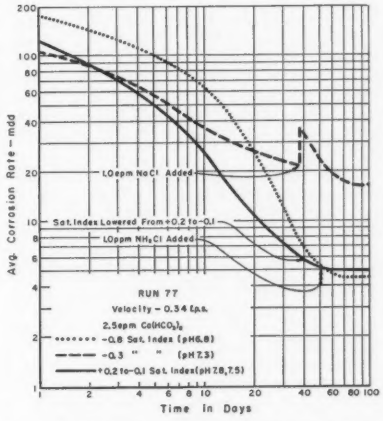
1.0 epm NaCl Added
Sat. Index Lowered From +0.2 to -0.1
1.0 ppm NH4Cl Added
RUN 77
Velocity - 0.34 fps.
2.5 epm Ca(HCO3)2
-0.8 Sat. Index (pH 6.8)
-0.3 " " (pH 7.3)
+0.2 to -0.1 Sat. Index (pH 7.8, 7.5)
Avg. Corrosion Rate - mdd
Time In Days

Figure 9—Corrosion rate variation with time for machined cast iron at 0.34 fps.

lar growths, but to a lesser extent, developed on the specimens in water at —0.1 saturation index.

The effect of adding 56 ppm sodium chloride increased the corrosion rate. A later illustration shows that the simultaneous reduction of saturation index was not responsible for the increase in rate at this high calcium level.

The single addition of 5 ppm SiO_2 after 17 days had no apparent effect on the corrosion rate. No attempt was made in this test to maintain this concentration.

Figure 9 provides similar data at 0.34 fps, but with chloramine present rather than free chlorine. The more rapid reduction of corrosion rate and the lower final corrosion rates testify to the effectiveness of greater velocity to improve the diffusion rate of calcium as the inhibitor. Reducing the saturation index had no effect on the corrosion rate with this relatively high calcium content.

Tubercles, similar to those occurring when free chlorine was present, were noted in the —0.3 saturation environment, but they were smaller in size and number.

The effect of adding 56 ppm sodium chloride after 36 days is clearly demonstrated.

Relative Influences

The relative influences of calcium concentration, saturation index, the chloride to alkalinity ratio, and chlorine were further investigated. The results of four test conditions using waters of 30 ppm calcium hardness are indicated in Figure 10. These specimens showed tuberculation in all cases, with or without chlorine or chloramine, and were similar in appearance to the specimens in water of 125 ppm calcium hardness at —0.3 saturation index, in Figures 8 and 9.

Although the calcium concentration was lower, the rate of corrosion after one day was less than that when 125 ppm calcium hardness was present since the velocity was greater and the pH higher. The rate of approach to equilibrium is slower than when 125 ppm calcium hardness was present.

Recent data provide results for water with 85 ppm calcium hardness and a 0.29 $(Cl + SO_4)$/alkalinity ratio. Various proportions of chloride and sulfate were used, but in these tests, no different rates of corrosion or degree of tuberculation were noted with sulfate than with chloride. The data have been grouped by velocities: 0.085 fps, 0.34 fps, and 0.85 fps. The results show the same general trend as exhibited in the data shown in Figures 8 and 9.

At the low velocity (Figure 11), the specimens in the water at zero saturation index had a faster rate of decrease and ended at a lower final rate of corrosion than those in waters of either the —0.3 or —0.8 saturation index. After 82 days, the saturation index was made more positive in two of the four solutions at —0.8 saturation index. There was an immediate decrease in corrosion rate for the change to both zero and —0.3 saturation index with this water of low calcium concentration.

At the intermediate velocity (Figure 12), the specimens generally had a

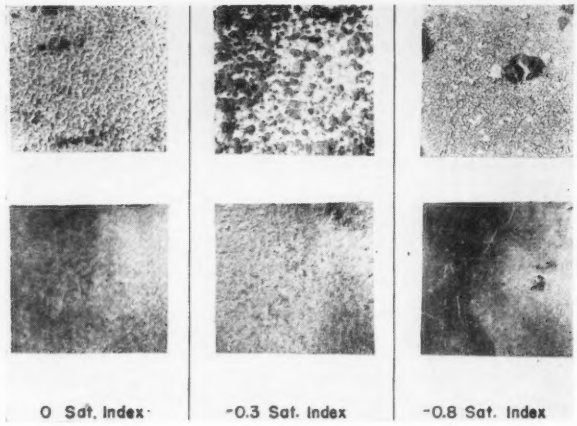

Figure 13—Typical corroded surfaces of cast iron specimens used to obtain data in Figure 12. Specimens are shown before and after cleaning.

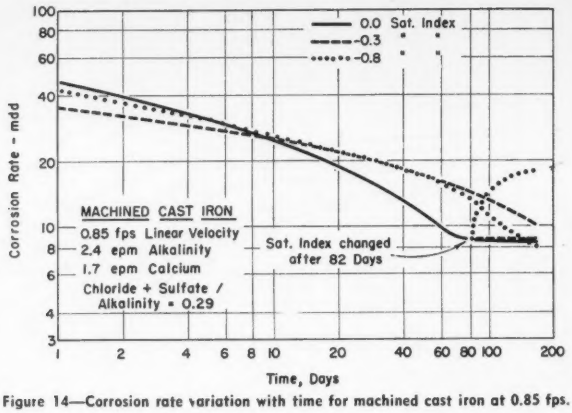

Figure 14—Corrosion rate variation with time for machined cast iron at 0.85 fps.

slightly greater decrease of corrosion rate than at the low velocity. For an undetermined reason, the specimens in water at —0.8 saturation index reached their equilibrium rate much quicker than did the specimens in waters at either the zero or —0.3 saturation index. The zero saturation index, however, provided the lowest final rate of corrosion. A change in saturation index after 82 days from —0.3 to —0.8 resulted in an increase of the corrosion rate, whereas a change in the positive direction to zero saturation index resulted in a decrease of the corrosion rate.

Typical specimens for the three degrees of saturation index with respect to calcium carbonate are shown before and after cleaning in Figure 13.

Specimens at the high velocity (Figure 14) had lower initial corrosion rates. However they had a slower rate of approach to equilibrium, similar to the results shown previously in Figure 10. A change from zero to —0.8 saturation index after 82 days resulted in an increase in the corrosion rate. The change from zero to —0.3 saturation index apparently was not significant enough to change the corrosion rates.

The specimens in water at —0.8 saturation index showed primarily a general corrosion attack as did the specimens in tests at the other velocities and at 125 ppm calcium hardness.

The specimens in water at —0.3 saturation index had a rough surface of corrosion products. Tubercles occurred over the entire surface of the specimen.

The specimens at zero saturation index exhibited corrosion products similar to those occurring in water at —0.3 saturation index; however, there were fewer and less pronounced tubercles.

Discussion

1. It has been established that bicarbonate in the absence of calcium is a mild, although effective inhibitor to corrosion of steel, as contrasted to the accelerative effect of chloride and sulfate anions. Alkalinity, a measure of bicarbonates, exerts a singular or independent inhibiting effect on corrosion.

2. It also has been established that calcium hardness, independent of the saturation index, is a mild, although effective inhibitor to corrosion. It is probable that this is the case only in the presence of alkalinity.

3. The finding that calcium in the presence of alkalinity, regardless of pH or saturation index, is an effective inhibitor to corrosion is not inconsistent with theory and experience. This is because the basic corrosion reaction is conducive to the formation of calcium carbonate at the cathode points in the corrosion cell even though the water environment is below saturation with respect to calcium carbonate. The rate at which such deposition may take place is increased by higher concentrations of calcium and/or presumably the alkalinity. The rate of deposition also is increased by higher velocities. The rate is further increased by pH adjustment at or above the saturation pH for calcium carbonate.

4. The finding that tubercles form under conditions below, but near, complete protection is consistent with the well-known action of inhibitors to induce pitting corrosion, rather than general corrosion, when present in a concentration that is insufficient to produce complete protection. This relation is confirmed by the observation of pitting corrosion or "deferrotization" on the specimens which showed tuberculation. The fact that tubercles do form apparently is due to the deposition of a supporting structure of calcium carbonate with or in the normal corrosion product of ferric hydroxide in aerated waters.

If the saturation index is not sufficiently close to zero or the concentrations of calcium and/or alkalinity are too low, a supporting structure may not be developed, although appreciable protection may be afforded by calcium carbonate imbedded in the rust deposit from generalized corrosion. It was observed on specimens in waters of —0.8 saturation index with high calcium at pH 6.8 (Figures 8 and 9) that the specimens were coated with a whitish red deposit of sufficient thickness (about 1/16 inch) and rigidity to continue to adhere even though this deposit was cracked for distances of one-half inch. There were no pits under this deposit and it served as an effective barrier to the diffusion of oxygen and other corrosive agents.

Conclusions

1. As deduced from the data derived from these tests, the corrosivity of air-saturated domestic waters is dependent on: (a) the *proportion* of corrosive agents to the inhibitive agents, (b) the *concentration* and degree of effectiveness of the corrosive and inhibitive agents and (c) the *velocity* of flow which influences the rates of diffusion of both the corrosive and inhibitive agents to or through the protective surface.

Corrosive agents in domestic waters are chloride and sulfate ions. Inhibitive agents in domestic waters are bicarbonate, carbonate, hydroxide, and calcium ions. The relative effectiveness of each is not definitive and may be influenced by one or more of the others.

It is axiomatic that for each specific condition, a minimum concentration of the inhibitor must be present for complete protection.

Increasing velocity provides increasing protection with low proportions of corrosive agents to inhibitive agents. On the other hand, with increasing velocities, as this proportion increases, the degree of protection decreases.

2. The intermediate proportions of corrosive to inhibitive agents, which result in incomplete protection at a particular velocity, are conducive to pitting and/or tuberculation. The problem of designing water treatment to avoid tuberculation of cast iron is limited to such waters as already contain inhibitors, but which are in concentrations which are insufficient to provide *complete* protection. The problem is jointly concerned with maintaining or creating a velocity of flow which is sufficient to provide adequate diffusion, transport, or movement of the inhibitor to the point of effectiveness.

Acknowledgment

These studies are supported by Research Grant G-4007 (R) from the National Institutes of Health, U. S. Public Health Service. The physical facilities for the laboratory investigations were furnished by the Illinois State Water Survey. The authors wish to thank Mary C. Brooks and Wesley Walters of the Illinois State Water Survey for their laboratory assistance.

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The Current-Voltage Relationship Of Galvanic Anode Arrays in Cathodic Protection*

By L. J. WALDRON and M. H. PETERSON

Abstract

The current output of full-scale arrays of several anode sizes in use by the U. S. Navy for the cathodic protection of ship hulls were determined. Impressed-current anodes formed from sheet steel were substituted for conventional galvanic anodes to reduce the weight and number of arrays necessary to obtain the desired information. Five anode sizes were investigated. A 1500-foot steel sea wall located in water with a resistivity of 34 to 38 ohm-cm acted as an unpolarizable cathode. The output currents were determined for driving potentials of 0.1, 0.2, 0.5, 0.7, and 1.0 between the cathode and the anode arrays; hence the data can be used to estimate for any galvanic material both the initial current output of an anode array, and the continuing current output against a cathode polarized to a known potential.

The anodes in all arrays investigated suffered mutual interference as indicated by decreased current outputs from individual anodes as the number of anodes in the array increased. It was found that the addition of anodes is more efficient than a moderate separation of anodes in increasing the total current output.

An empirical equation was derived from the data of the continuous linear arrays which relates the current output to total anode area and driving potential. It may be used to estimate the current output of arrays for which more specific data have not been obtained, but these estimations should be confirmed by experimentation wherever possible. 5.2.2

Introduction

IN THE SPRING of 1956, the Bureau of Ships indicated that there was an urgent need for design information relative to the current outputs to be expected from arrays of anodes of several sizes and materials when mounted on marine hulls. The anodes currently in use which were of particular interest to the Bureau were 3 x 12 x 1¼ inch, 6 x 12 x 1¼ inch, 4 x 4 x 48 inch, and 7 x 7 x 36 inch aluminum anodes; 4 x 4 x 48 inch, 7 x 7 x 36 inch, and 4 x 10 x 60 inch magnesium anodes; and 3 x 12 x 1¼ inch and 6 x 12 x 1¼ inch zinc anodes. The experiments described herein were designed to fill this need.

Experimental Procedure

The investigations were carried out at the Norfolk Group, Atlantic Reserve Fleet docking area at the Norfolk Naval Shipyard, Portsmouth, Virginia. Located here is a 1500-foot steel sea wall in water about 20 feet deep with a resistivity of 34 to 38 ohm-cm. This sea wall constituted a virtually unpolarizable cathode.

Impressed-current steel anodes were used rather than galvanic anodes in order to reduce the weight of the individual anode arrays and the number of arrays which would be required. By varying the potential difference between the anode and the cathode, it was possible to obtain data which could be used to estimate the current outputs of galvanic anodes of various potentials. The anode sizes chosen for the investigation were 3 x 12 x 1¼ inches, 6 x 12 x 1¼ inches, 4 x 4 x 24 inches, 7 x 7 x 36 inches, and 4 x 10 x 60 inches. A maximum of six anodes per array was used in arrays of each anode size except the 4 x 4 x 24 inch size; for this anode size, twelve anodes were used in the array so that the total current output would be comparable to that of six standard 4 x 4 x 48 inch anodes.

The anodes were U-shaped sections formed from 22 gage hot-rolled and pickled mild steel. The inner surface of all anodes was painted to provide a nonconductive surface, and the anodes were attached to wood cleats and mounted in line on ¾-inch plywood. The physical dimensions of the anode assemblies and the plywood sheets are listed in Table 1 and a typical conformation is shown in Figure 1. The ends of the anodes were separated sufficiently to ensure electrical isolation. A sheet of steel was spot welded over the exposed ends of the first and last anodes of each array (Figure 2).

The complete anode assemblies were suspended from the sea wall at a depth of approximately four feet with the anodes facing seaward and with the plywood backing a few inches from the sea wall. The plywood served as an electrical shield, and extended beyond the anodes in all assemblies except that of the 4 x 10 x 60 inch anodes, where the weight precluded excess plywood.

A schematic diagram of the experimental circuit is shown in Figure 3. Direct current to the anodes was supplied by a full-wave rectifier controlled by an autotransformer. A single-pole single-throw knife switch and 0.01-ohm shunt were installed between each anode and the rectifier so that the anodes could be activated single or in multiple and the current outputs of the individual anodes monitored under all conditions. The meter used across the shunts was a multiscale millivoltmeter of high enough resistance and of sufficient intrinsic accuracy so that readings were accurate within 2 percent. Each anode also could be directly connected through a single-pole multi-position switch and a 100,000-ohm-per-volt voltmeter to the sea wall, so that the anode-cathode potential difference (also called driving potential) could be read for each anode separately.

Various driving potentials were applied, and the resulting currents were determined after approximately five minutes of operation. The driving potentials were 0.1 volt, 0.2 volt, 0.5 volt, 0.7 volt, and 1.0 volt, and the following current measurements were made for all anode assemblies except the 4 x 4 x 24 inch assembly:

1. The current output of each anode acting independently.

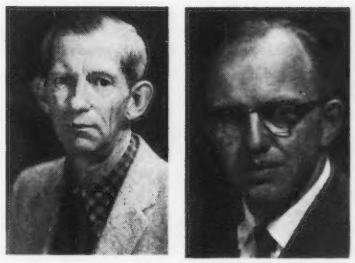
2. The current output of each anode in continuous arrays of two, three, four, and six anodes.

3. The total current outputs of these continuous arrays of two, three, four, and six anodes.

Because the 4 x 4 x 24 inch anode assembly contained 12 anodes, the measurements were altered to the following:

1. The current output of each anode acting independently.

2. The current output of each anode in continuous arrays of two, three, four, eight, and twelve anodes, and in discon-



Waldron Peterson

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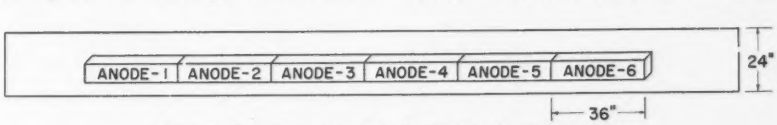

Figure 1—The conformation of the 7 x 7 x 36 inch anode assembly.

★ Submitted for publication July 15, 1957. A paper presented at the Thirteenth Annual Conference, National Association of Corrosion Engineers, St. Louis, Missouri, March 11-15, 1957.

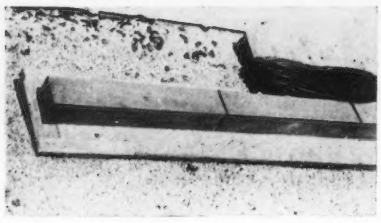

Figure 2—End view of the 7 x 7 x 36 inch anode assembly.

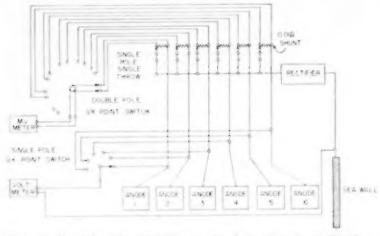

Figure 3—Circuit diagram of the test installation.

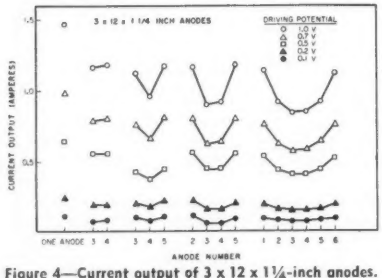

Figure 4—Current output of 3 x 12 x 1¼-inch anodes. Numbers at bottom designate position of anodes in the arrays numbered consecutively from left to right.

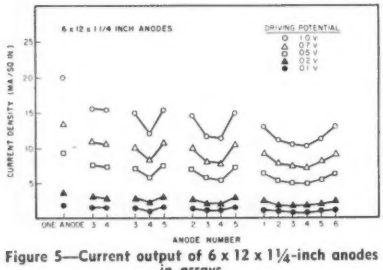

Figure 5—Current output of 6 x 12 x 1¼-inch anodes in arrays.

tinuous arrays of three, four, and six anodes.

3. The total current output of each array.

The major experimental errors were in the control of the driving potential. These errors were of several types. First, the implicit assumption that the open-circuit potentials of the sea-wall cathode and the anodes were equal was in error since the sea wall was a well rusted steel surface while the anodes were formed from bright, unrusted mild steel. This initial potential difference was minimized by operating the anodes at current densities of about 100 milliamperes per square foot for several hours prior to making measurements in order to build up an oxide film on the anodes. After this treatment the open-circuit potential difference between the

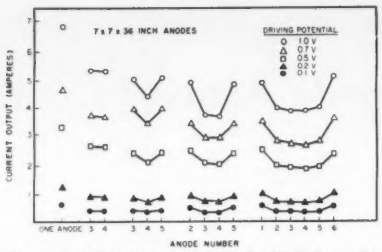

Figure 6—Current output of 7 x 7 x 36 inch anodes in arrays.

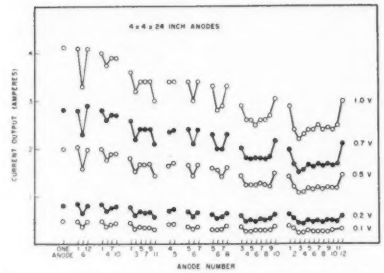

Figure 7—Current output of 4 x 4 x 24 inch anodes in arrays.

TABLE 1—Physical Dimensions of the Anode Assemblies

Anode Size (Inches)	Assembly Length (Inches)	Assembly Width (Inches)	Shield Length (Inches)	Shield Width (Inches)
3 x 12 x 1¼	72	3	96	24
6 x 12 x 1¼	72	6	96	24
4 x 4 x 24	288	4	288	10
7 x 7 x 36	216	7	288	24
4 x 10 x 60	360	10	360	10

anode and cathode averaged about 10 millivolts, with an extreme difference of 30 millivolts. This was considered negligible for the purposes of this experiment.

A second possible source of error was uneven current distribution, since the sea wall did not present a plane surface at a uniform distance from the anodes. In fact, the sea wall presented a corrugated face with a depth of about six inches between the raised and sunken portions of the surface.

A third possible source of error was considering the sea wall to be a cathode of uniform potential surface and neglecting any slight local potential differences which might have been present on the cathode.

Examination of the data indicated that, within the limits of accuracy of interest in this work, the effects of these potential differences were negligible.

Experimental Results

Figures 4-8 show the individual current output per anode for each of the anode arrays at the five driving voltages. All of the anode arrays are linear and continuous except that of the 4 x 4 x 12 inch anodes; for these anodes, current output per anode also is shown for several noncontinuous anode arrays.

As anticipated, the current per anode decreased as the number of anodes in the string increased, indicating mutual interference between anodes when current was flowing from more than one

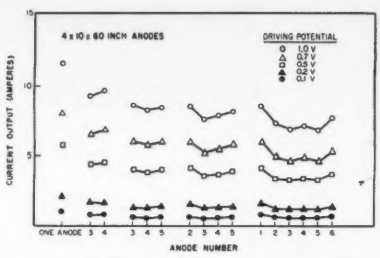

Figure 8—Current output of 4 x 10 x 60 inch anodes in arrays.

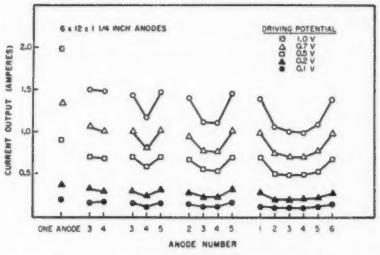

Figure 9—The current density of each anode in the 6 x 12 x 1¼ inch anode arrays.

anode. In general the center anodes showed less current output (more mutual interference) than those on the ends of the string. The decrease in current output per anode was greater at high driving potentials than at low, but the percentage decrease in current output was relatively constant (Table 2). Within the requirements of design purposes, the percent of mutual interference was equal for all of the anodes considered except the 6 x 12 x 1¼ inch anode which has a markedly higher degree of interference between anodes.

The possibility was considered that this interference effect might not be real, but might simply reflect the difference in area between the end anodes and the remaining anodes in the string. Accordingly, the apparent current density obtained by dividing the total current by the exposed area for each anode of the 6 x 12 x 1¼ inch anode string also was plotted (Figure 9). Inspection reveals that the shape of the curves in Figures 4-8 and Figure 9 are almost identical, indicating that very little of the reduced current output could be due to the slightly decreased surface area of the center anodes as compared to the end anodes.

The total current output of each of the continuous arrays as a function of the driving potential is given in Table 3 and plotted in Figures 10-14. If there were no experimental error, these curves would be straight lines through the origin; as shown, they are empirical representations of the data and include the experimental error. In any event this error is negligible for the purposes of this report.

Figures 10-14 can be used to estimate the current output of any galvanic or impressed current anode or continuous array of anodes of the sizes included in the experiment. This represents the total current output of the array operating against a cathode close to the anode in water of 34 to 38 ohm-cm resistivity. This current should be a close approximation to the maximum current to be

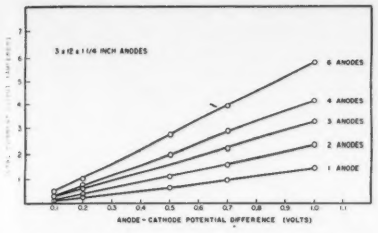

Figure 10—Total current outputs of continuous linear arrays of the 3 x 12 x 1¼ inch anodes.

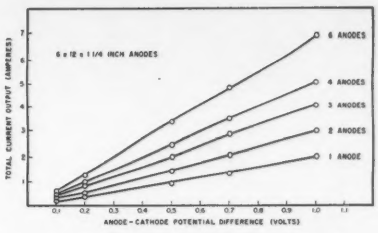

Figure 11—Total current outputs of continuous linear arrays of the 6 x 12 x 1¼ inch anodes.

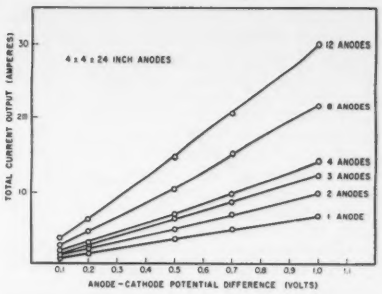

Figure 12—Total current outputs of continuous linear arrays of the 4 x 4 x 24 inch anodes.

TABLE 2—The Maximum Mutual Interference Encountered in Linear Anode Arrays

Anode Size (inches)	ANODE-CATHODE POTENTIAL DIFFERENCE								
	0.1 Volt			0.5 Volt			1.0 Volt		
	Current			Current			Current		
	Avg.* (amp)	Min.** (amp)	Decrease (%)	Avg. (amp)	Min. (amp)	Decrease (%)	Avg. (amp)	Min. (amp)	Decrease (%)
x 12 x 1¼	0.11	0.07	38.9	0.64	0.40	37.5	1.47	0.85	42.7
x 12 x 1¼	0.19	0.09	59.5	0.91	0.47	48.9	1.98	0.99	50.0
x 4 x 24	0.50	0.27	44.9	2.01	1.16	41.3	4.12	2.40	41.7
x 7 x 36	0.67	0.41	39.8	3.26	1.93	41.0	6.81	3.90	42.8
x 10 x 60	1.14	0.72	37.5	5.55	3.40	38.7	11.7	6.70	42.6

* The current output of an anode operating singly.
** The estimated minimum current output of the center section of the longest array used.

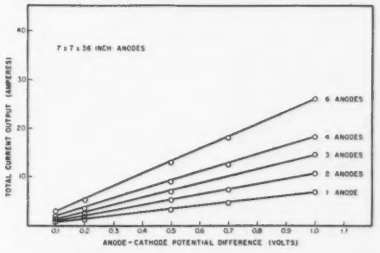

Figure 13—Total current outputs of continuous linear arrays of the 7 x 7 x 36 inch anodes.

TABLE 3—The Current Outputs of Continuous Linear Arrays of Impressed-Current Steel Anodes

Anode Size (inches)	Number of Anodes in Array	Area of Anode (sq. inches)	TOTAL CURRENT OUTPUT OF ARRAY (amp) Anode-Cathode Potential Difference				
			0.1 Volt	0.2 Volt	0.5 Volt	0.7 Volt	1.0 Volt
3 x 12 x 1¼	1	64	0.11	0.24	0.64	0.98	1.47
	2	124	0.15	0.38	1.10	1.59	2.34
	3	186	0.29	0.60	....	2.23	3.25
	4	247	0.32	0.74	1.99	2.86	4.16
	6	383	0.48	1.00	2.72	3.93	5.79
6 x 12 x 1¼	1	99	0.18	0.36	0.91	1.33	1.98
	2	191	0.30	0.58	1.42	2.05	2.98
	3	287	0.40	0.80	1.97	2.82	4.07
	4	383	0.50	0.95	2.41	3.47	5.05
	6	595	0.59	1.24	3.33	4.82	6.88
4 x 4 x 24	1	291	0.49	0.82	2.01	2.82	4.2
	2	576	0.72	1.38	3.35	4.75	6.73
	3	864	1.08	1.98	4.75	6.9	9.8
	4	1152	1.33	2.44	6.18	8.60	12.3
	8	2304	2.51	4.40	10.40	14.95	21.6
	12	3488	3.53	6.17	14.55	20.45	29.85
7 x 7 x 36	1	764	0.67	1.27	3.26	4.67	6.81
	2	1491	0.90	1.89	5.10	7.35	10.7
	3	2237	1.28	2.53	6.90	11.40	14.6
	4	2982	1.81	3.45	9.00	12.6	18.3
	6	4582	2.86	5.14	12.88	18.1	26.2
4 x 10 x 60	1	1093	1.14	2.22	5.55	7.93	11.7
	2	2160	1.86	3.56	9.1	13.1	19.0
	3	3240	2.15	4.40	12.1	17.5	25.2
	4	4320	2.82	6.11	15.7	22.2	31.9
	6	6560	4.57	8.69	21.8	30.4	43.8

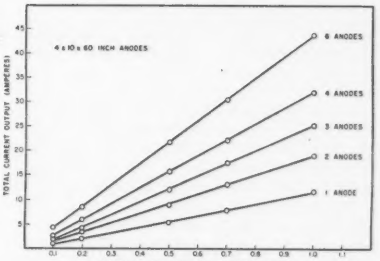

Figure 14—Total current outputs of continuous linear arrays of the 4 x 10 x 60 inch anodes.

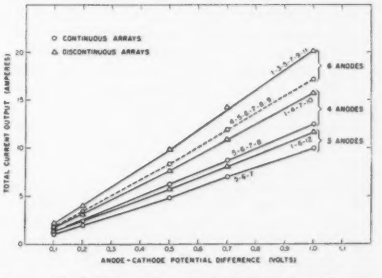

Figure 15—The current output of several continuous and discontinuous linear arrays of the 4 x 4 x 24 inch anodes as a function of the driving voltage. The points shown for a continuous array of six anodes were interpolated from the data obtained for the four-anode and eight-anode arrays.

expected from anodes operating against a large cathode in sea water. To make an accurate estimate of current output it is necessary to know the anode-cathode potential difference. The cathode potential should be measured using any of the standard half cells. The current output obtained by using such measured values is the maximum initial output to be expected against an unpolarized cathode; as the cathode polarizes the current will decrease. The current at any time may be estimated if the polarized potential of the cathode at that time is known or can be estimated.

Also investigated was the reduction in the mutual interference between anodes which could be effected by operating the anodes in noncontinuous arrays with spacing between the active anodes. The total current outputs of noncontinuous arrays of three, four, and six 4 x 4 x 24 inch anodes were determined. The data are plotted in Figure 15 and show that, as expected, a given number of anodes in a noncontinuous array always produced more current than the same number of anodes arranged in a continuous array. However, this increase in current output was rather small, particularly at low driving voltages, even when the active anodes were widely separated. In every case more current was produced by adding an anode to the continuous array than by spreading the anodes to reduce the interference effect. This suggests that in most practical installations, particularly where expensive shielding is used around the anode, the preferred method of increasing current output will be the addition of anodes.

A General Equation to Estimate Current Output

Efforts were made to develop a relationship between some geometric property of continuous anode arrays and the current output to be expected. The rela-

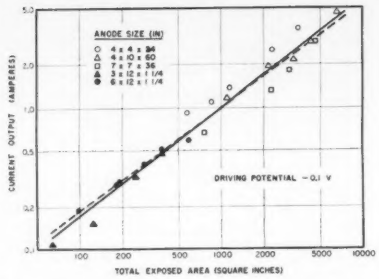
ANODE SIZE (IN)
4 x 4 x 24
4 x 10 x 60
7 x 7 x 36
3 x 12 x 1 1/4
6 x 12 x 1 1/4
DRIVING POTENTIAL —0.1 V
CURRENT OUTPUT (AMPERES)
TOTAL EXPOSED AREA (SQUARE INCHES)

Figure 16—Logarithm of current output of continuous linear anode arrays as a function of the logarithm of total exposed anode area. The solid lines represent the least-squares fit to the plotted points on the individual graphs, while the broken lines are plots of an equation derived by combining all the data for the five voltages. Driving potential was —0.1 volt.

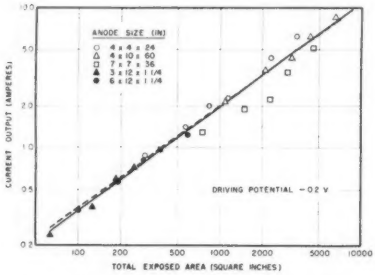
ANODE SIZE (IN)
4 x 4 x 24
4 x 10 x 60
7 x 7 x 36
3 x 12 x 1 1/4
6 x 12 x 1 1/4
DRIVING POTENTIAL —0.2 V
CURRENT OUTPUT (AMPERES)
TOTAL EXPOSED AREA (SQUARE INCHES)

Figure 17—Logarithm of current output of continuous linear anode arrays as a function of the logarithm of total exposed anode area. Driving potential was —0.2 volt.

tionship which best fits the data is shown in Figures 16-20 where the logarithm of the current output is plotted as a function of the logarithm of the total exposed area of the anode. All of the points fit the curve reasonably well except those for the 7 x 7 x 36 inch anode arrays, but this fit is to some extent fortuitous due to the generally similar geometry of the arrays used. If the data for the individual anode sizes are examined separately, it will be found that the points for a given anode size give a better fit to a straight line, but that these lines vary slightly in slope and intercept. This is undoubtedly indicative that the current output of an anode is not a function of the exposed area alone, and that other parameters are also important in determining the current output.

Despite the deviations mentioned above, it was felt that the fit was good enough to warrant the derivation of a general equation relating driving voltage, exposed anode area, and current output. The data for the five anode sizes and five driving voltages were combined by the method of moments (equivalent to a least-squares fit to the data) to yield

$$\log_{10} I = 0.727 \log_{10} A + \log_{10} \Delta E - 1.188$$

where

I = total current output of the array in amperes

ΔE = anode-cathode potential difference in volts

A = total exposed area of the array in square inches.

In Figures 16-20 the solid lines represent the least-squares fit to the data for each driving potential, while the broken lines show the general relationship given by the equation. Agreement is satisfac-

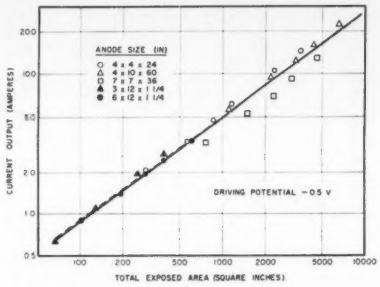
ANODE SIZE (IN)
4 x 4 x 24
4 x 10 x 60
7 x 7 x 36
3 x 12 x 1 1/4
6 x 12 x 1 1/4
DRIVING POTENTIAL —0.5 V
CURRENT OUTPUT (AMPERES)
TOTAL EXPOSED AREA (SQUARE INCHES)

Figure 18—Logarithm of current output of continuous linear anode arrays as a function of the logarithm of total exposed anode area. Driving potential was —0.5 volt.

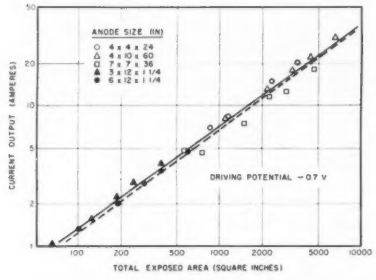
ANODE SIZE (IN)
4 x 4 x 24
4 x 10 x 60
7 x 7 x 36
3 x 12 x 1 1/4
6 x 12 x 1 1/4
DRIVING POTENTIAL —0.7 V
CURRENT OUTPUT (AMPERES)
TOTAL EXPOSED AREA (SQUARE INCHES)

Figure 19—Logarithm of current output of continuous linear anode arrays as a function of the logarithm of total exposed anode area. Driving potential was —0.7 volt.

tory for all driving potentials. This empirical relationship between driving voltage, current, and anode area also is presented as a nomogram in Figure 21.

While it is not recommended that this relationship be used to calculate the current outputs of anode arrays for which empirical data such as that of Figures 10-14 are available, it may be used with caution to form an estimate of the current outputs of other anode arrays of similar geometry. Such preliminary calculations should be reinforced by experimental data wherever practical.

Summary and Conclusions

Reliable curves have been obtained for the current-driving voltage relationship of arrays of 3 x 12 x 1¼ inch, 6 x 12 x 1¼ inch, 4 x 4 x 24 inch, 7 x 7 x 36 inch, and 4 x 10 x 60 inch impressed current or galvanic anodes. These curves give suitable design information regarding the initial current output to be expected against an unpolarized steel cathode in sea water, or the continuing current output of an array against a cathode polarized to a known potential.

The anodes in all of the arrays investigated suffered mutual interference as indicated by the decreased current output per anode as the number of anodes increased. The same degree of mutual interference was found for all of the anode types except the 6 x 12 x 1¼ inch anode which showed considerably greater interference.

It was shown that moderate separation of anodes in an array is an inefficient method of increasing the current output of the array. In most practical installations increased current output could be obtained more economically by adding additional anodes to the array.

A general equation which may be used to calculate the current output of arrays of anodes of other sizes at the expense

ANODE SIZE (IN)
4 x 4 x 24
4 x 10 x 60
7 x 7 x 36
3 x 12 x 1 1/4
6 x 12 x 1 1/4
DRIVING POTENTIAL —1.0 V
CURRENT OUTPUT (AMPERES)
TOTAL EXPOSED AREA (SQUARE INCHES)

Figure 20—Logarithm of current output of continuous linear anode arrays as a function of the logarithm of total exposed anode area. Driving potential was —1.0 volt.

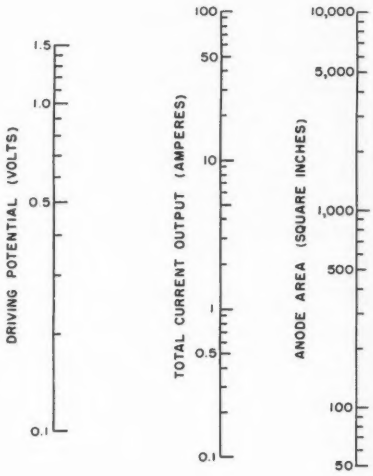

Figure 21—A nomogram for the calculation of the current outputs of galvanic anodes.

of some loss of accuracy has been developed and presented as a nomogram. This relationship derived for waters of 34-38 ohm-cm resistivity, involves the parameters current output, driving voltage, and anode area, and may be used to calculate any of these if the other two are known.

Acknowledgment

The cooperation of the Norfolk Reserve Fleet Group in furnishing facilities and personnel for this work is gratefully acknowledged.

DISCUSSION

Comments by Andre J. deBethune, Boston College, Chesnut Hill, Mass.:

Data presented in this paper represent a valuable addition to our understanding of current distribution in cathodic protection. On the basis of their data the authors suggest that the total current output, per unit of driving potential, in amperes per volt (which is equal to the conductance of the electrolytic current path in mhos) increases as the 0.727 power of the anode area A (in square inches) as shown by their empirical equation which is here rewritten in the form

$$I_{amp}/E_{volt} = K_{mho} = 0.065\, A_{sq.\,in.}^{0.727} \quad (1)$$

The same data can be analyzed in a different way to yield information regarding the contribution to the total electrolyte conductance in mhos, of the two ends of the anode array and of each lineal foot of anode length. Waldron and Peterson's anodes were arranged in linear arrays of 1 anode up to 12 anodes, ranging in total length from 1 foot to 30 feet. The data given in Table 3 or in Figures 10-14 can be analyzed as follows: Let the total current output I (in amperes) divided by the driving potential E (in volts) be plotted as ordinates *versus* the number *n* in the array as abscissae. The data for the several anode arrays yields a family of remarkably good straight lines of the form

$$I_{amp}/E_{volt} = K_{mho} = K_{2e} + K_a n \quad (2)$$

where K_{2e} is the intercept, and K_a the slope, in the plot of total conductance K *versus* anode number *n*. The intercept K_{2e} may be interpreted as the contribution of the two ends of the anode array to the electrolyte conductance. The slope K_a then represents the conductance contribution of the lineal length of one single anode in the array. For the anode arrays studied by the authors, the conductance constants given in Table 4 can be calculated from their data. (The steel anodes used were U-shaped steel plates, with their inner surfaces painted to provide a non-conducting surface. A sheet of steel was spot welded over the exposed ends of the first and last anode of each array.)

Calculation of Total Electrolyte Conductance K

It is interesting to compare the calculation of total electrolyte conductance K by the equation (1) and by equation (2). For example, for the array of four 6 x 12 x 1¼ inch anodes with a total area of 1152 square inches, the electrolyte conductance is equal to 4.94 mho by equation (1); 4.80 mho by equation (2); and 4.75 to 5.05 with an average of 4.91 mho (experimental). This is excellent agreement. In other instances, the agreement is less good. For the array of twelve 4 x 24 x 4 inch anodes, with a total area of 3488 square inches, the electrolyte conductance is 24.6 mho by equation (1); 31.9 mho by equation (2); and 29.1 to 35.3 with an average of 30.9 mho (experimental). Equation (1) is low here as compared with equation (2) and with the experimental values. However, the deviation of equation (1) from equation (2) nowhere exceeds ±22 percent. Equation (1) attempts to fit the five sets of anode geometries with only two empirical constants. Equation (2) gives a better fit to the data, but requires five sets of two empirical constants to handle the five anode dimensions studied. The constants of equation (2) are more amenable to theoretical interpretation than those of equation (1), however.

Table 4 also lists the conductance K_1 per lineal foot of anode length (in mho/ft). The total conductance of any particular anode array (of the same dimensions as those studied by the authors) can then be computed from the alternative equation

$$I_{amp}/E_{volt} = K_{mho} = K_{2e} + K_1 L_{ft} \quad (3)$$

where L is the total length of the anode or anode array in feet. Waldron and Peterson's anodes were mounted on plywood backings of the widths tabulated, and suspended four feet deep in Norfolk harbor water a few inches away from the essentially infinite cathode.

Corrections in Conductance Constants

Whenever the anode conductance constants K_{2e} and K_1 tabulated here are to be used in further design calculations, the following corrections should be noted: (1) if the sea water resistivity ρ (in ohm cm) differs from that of the water used by Waldron and Peterson, the conductance constants should be multiplied by the ratio $36/\rho$, (2) if the shield width or the anode-cathode spacing are reduced the conductance constants should be correspondingly increased. Conversely, if the shield width or the anode-cathode spacing are increased, the conductance constants should be correspondingly reduced. The increase or decrease will be small however, and can be estimated for the lineal conductance K_1 by setting K_1 proportional to the theoretical expression: $\log (L_A + L_C + 2L_G) - \log 2L_G$. In this equation, L_A is the total anode width (including the contribution of the anode depth), L_C is the total cathode width, and L_G is the distance from the edge of the anode to the edge of the anode shield plus the shield-cathode spacing at its narrowest point (A. J. deBethune, *Corrosion*, in preparation). Thus, in the case of Waldron and Peterson's 10 x 60 x 4 inch anodes, the total anode width L_A is $4 + 10 + 4 = 18$ in $= 1.5$ ft.

The cathode width L_C is 20 ft. An increase in the anode to shield to cathode spacing from 6 inches (0.5 foot) to 1 foot to 2 feet should reduce the lineal conductance term K_1 in the ratio 1 to 0.793 to 0.600. Unfortunately, the value of the exact spacing used by the authors was not given by them for the anodes they studied beyond the statement that the plywood backing was immersed a few inches away from the cathode.

The effect of a variation in the anode to shield to cathode spacing on the two-ends conductance term K_{2e} is much harder to estimate. To a first approximation, this term may be taken as independent of this spacing, (i.e., as roughly constant for each anode dimension). It is interesting to compare the observed two-ends conductance K_{2e} with that calculable theoretically for two hemispherical anode ends of radius r (to an infinite cathode) equal to $4\pi r/\rho$ (C. Wagner, *J. Electrochem. Soc.*, **99**, 4 (1952); E. R. Shepard and H. J. Graeser, *Corrosion*, **6**, 360 (1950)). For 36 ohm cm water, the values of K_{2e} tabulated above yield the set of "equivalent hemispherical radii" for the two anode ends (See Table 5). The comparison between the "radii" calculated there with equivalent "radii" that could be estimated from the geometrical dimensions of the anode ends, is most heartening indeed. In every instance, the observed "equivalent conductance radius" of the anode ends runs between 10 percent and 30 percent of the total anode width. If the anode ends were circular in shape, the total anode width would be equal to the circumference or $2\pi r$, and r would be equal to 15.9 percent of the total anode width for such a circular geometry. Thus the "equivalent conductance radius" of the two anode ends is, in every instance, of the right order of magnitude as compared with the anode end geometry.

The conductance contributions of the two anode ends, and of each lineal foot of anode length, as deduced from Waldron and Peterson's data and corrected for sea water resistivity and for anode-shield-cathode spacing, can be used to advantage. They can be used with a fair degree of confidence to calculate the sea path conductance (reciprocal resistance) of any particular array of anodes of the same geometry as those studied by the authors, to a very large cathode. For discontinuous arrays of the type reported by the authors in Figure 15, (where the gap between adjacent anodes was short, i.e., 2 to 8 feet) somewhat better agreement with the data may be obtained. This will occur if the two-ends contribution K_{2e} is reduced by approximately 50 percent for each pair of adjacent intermediate anode ends, while the constants K_{2e} and K_1 are retained unmodified for the pair of terminal anode ends and for the entire anode length, respectively, of the discontinuous array.

Acknowledgment

The analysis reported above was the result of cooperative discussions between A. J. deBethune and C. W. Ambler, American Zinc Co.; J. A. H. Carson, Pacific Naval Establishment, Royal Canadian Navy; E. E. Nelson, Socony Mobil Oil Co.; H. S. Preiser, Bureau of Ships, U. S. Navy; and B. H. Tytell, Boston Naval Shipyard, U. S. Navy. Some of these discussions occurred at the Sea Horse Institute Meeting, sponsored by the International Nickel Co., Wrightsville Beach, N. C., June, 1957. The contributions of all are hereby gratefully acknowledged.

Reply by L. J. Waldron and M. H. Peterson:

Dr. deBethune has reanalyzed the data presented in our paper in terms of the total conductance K_{mho}. We redetermined what we consider as the most representative values for the total conductance from the slopes of the indi-

TABLE 4—Conductances of Anode Arrays

ANODE SIZE (inches)	Plywood Backing Width (inches)	CONDUCTANCE		
		Of two ends, K_{2e} (mho)	Of lineal length of one anode, K_a (mho)	Per lineal foot, K_1 (mho/ft)
3 x 12 x 1¼	24	0.5	0.85	0.85
6 x 12 x 1¼	24	0.8	1.00	1.00
4 x 24 x 4	10	2.1	2.48	1.24
7 x 36 x 7	24	2.7	3.29	1.31
10 x 60 x 4	10	5.0	6.5	1.30

TABLE 5—Equivalent Hemispherical Radii

Anode Size (inches)	Total Anode Width (inches)	Equivalent Hemispherical End Radius r Calculated from Observed Two-Ends Conductance K_{2e} (inches)
3 x 12 x 1¼	5½	9/16
6 x 12 x 1¼	8½	29/32
4 x 24 x 4	12	2 1/32
7 x 36 x 7	21	3 1/32
10 x 60 x 4	18	5 5/8

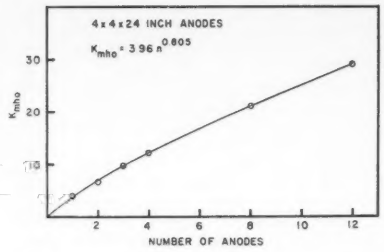

Figure 22—Total conductance of 4 x 4 x 24 inch anodes.

vidual plots of current vs. driving potential. By deriving the values of K from the slope of the curve any error due to an initial potential difference between the anode and cathode was eliminated.

These values of K were then fitted to the linear equation $I/E = K_{mho} = a + b\,n$ by the method of least squares. The fitting constants are as follows:

Anode Size	a	b
3 x 12 x 1¼	0.66	0.88
6 x 12 x 1¼	1.02	1.00
4 x 24 x 4	2.44	2.28
7 x 36 x 7	3.22	3.86
10 x 60 x 4	6.08	6.36

It can be seen that these values are in reasonable agreement with those determined by Dr. deBethune. However, when these equations are compared to a plot of K_{mho} it is evident that while the derived line appears to be a reasonable empirical fit of the data, the plotted data (Figure 22) exhibit marked non-linearity. We believe that an attempt to use the linear equations to estimate the current outputs of anode arrays containing significantly more anodes than used in the experiment would lead to appreciable error. An exponential expression of the form $\log_{10} K_{mho} = a + b \log_{10} n$ agrees more closely with the shape of the experimentally determined curve (Figure 22). The fitting constants for these equations are as follows:

Anode Size	a	b
3 x 12 x 1¼	0.168	0.762
6 x 12 x 1¼	0.284	0.701
4 x 24 x 4	0.598	0.805
7 x 36 x 7	0.824	0.751
10 x 60 x 4	1.063	0.736

It should be noted that neither the linear nor exponential expressions given above can be used to determine the current output of arrays of anodes of other sizes than those used in the experiment; this is the primary purpose of the nomogram given in the paper.

In the performance of the experimental work, the anodes and shields were completely preassembled before immersion. The current output value given for a single anode is the average of the six (or twelve) anodes in the array run separately. The current outputs given for two, three, four, and eight anodes were determined using only those anodes which were in the center of the array as indicated in Figures 4-9. From Figure 2 it will be seen that only the two terminal anodes of each array (Nos. 1 and 6 or 1 and 12) have ends which could contribute current. Under these conditions all current output measurements made with arrays of less than six anodes cannot be affected by conductance attributed to the anode ends. It is difficult, therefore, for the authors to understand how the intercepts of the linear equations could have any significant relation to the conductance contribution of the anode ends; we believe that these intercepts indicate only an attempt to fit non-linear data to a linear equation.

Any discussions of this article not published above will appear in the December, 1958 issue

Coal Tar Creosote Studies*

Part 1—A Method for the Accelerated Evaluation Of Marine Wood Preservatives

By T. R. SWEENEY, T. R. PRICE, R. A. SAUNDERS, SIGMUND M. MILLER and F. G. WALTON SMITH

Abstract

A method is presented for comparing the marine borer resistance of creosoted wood with that of wood treated with fractions of creosote obtained by distillation, solvent extraction, etc. The test method is accelerated by the use of test panels having a high surface-volume ratio and by leaching replicates of panels prior to exposure to borer attack

The mechanism of leaching in sea water and in accelerated leaching medium was studied by subjecting creosoted panels to four different treatments. The rate of leaching of material from the panels and the change in composition of the residual or leached creosote brought about by the differential diffusion of constituents from the wood were studied. Changes in composition were studied by means of distillation, average molecular weight and oxygen determinations, and infrared spectrophotometry.

The standard accelerated leaching of creosoted panels brings about a differential loss of creosote constituents comparable to the loss of constituents occurring during leaching in sea water, but at a more rapid rate. The material remaining in creosoted panels after nine months of leaching at ordinary temperature had almost the same distillation pattern as the material remaining after one day of leaching at 80 C, both leachings being conducted in flowing water. Upon extrapolation, this correspondence equates 16 days of accelerated leaching with 12 years of leaching at ordinary temperature.

2.3.2

Introduction

ALTHOUGH the soil block test[1,2] has become widely accepted as a means of determining the effectiveness of preservatives used to ameliorate terrestial deterioration of wood, no method of comparable utility and dependability has been forthcoming in the field of marine deterioration. This deficiency undoubtedly has played a role in the relatively slow progress made with preservatives against marine borers.

A renewed interest in weathering procedures[3] emphasizes the now generally recognized fact that the service life of treated wood is a function of both the toxicity and the permanence of the preservative. The ability of the preservative to remain in wood permanently and to exert its toxic (or inhibitory) function when held in wood are the qualities which must be assessed if a preservative test is to have any relationship at all to predictable service life. Studies on the weathering and permanence of creosote have been numerous although, with few exceptions, emphasis has been placed on terrestial weathering[4–12].

Confidence in the performance of a marine preservative, as indicated by accelerated testing, increases in proportion to the degree of similarity between test and service conditions. Service testing has obvious disadvantages; testing under natural conditions has the disadvantage of requiring an inordinately long time and a lack of control over some experimental variables. At the other end of the scale, essentially complete control of experimental variables could be maintained in a wholly artificial environment as was done by Becker and Schulze[13] but such a system would be far removed from and difficult to relate to actual service. In the method for evaluating preservatives presented here, treated panels are leached (weathered) under laboratory conditions and subsequently exposed to marine borer attack under natural conditions. This method was developed to permit comparisons of the preservative ability of coal tar creosote with that of some of its fractions; the method, when applicable, can be extended to other preservatives.

Selection of Parameters for Test Method

Leaching Medium

Marine borer (teredid) larvae were used in the first tests to select a suitable medium for accelerated leaching of creosote and its fractions. Active larvae were permitted to crawl about on both creosoted test panels and control panels of untreated wood. After three days of exposure to the creosoted panels none of the larvae recovered when transferred to fresh sea water. For periods of exposure up to three days the larvae recovered when transferred to fresh sea water, the period of recovery varying with the length of exposure. The interdependent factors of length of exposure and period of recovery were used as indices to determine the effectiveness of various leaching media.

The accelerated leaching media tested were boiling sea water, cold alkaline potassium dichromate solution, hydrochloric acid, aerated sea water and sodium hydroxide solution. After testing the action of the larvae on creosoted panels subjected to the various treatments it was found that aerated sea water and boiling sea water decrease the inhibitory properties of creosoted wood but that the acid, alkali and oxidizing baths are relatively ineffective. It was further found when the leached panels were exposed in the ocean to borer attack that the only effective treatment was boiling sea water. Later it was found that fresh water could be used with equal results, and that the temperature could be reduced to 80 C. For convenience and constancy the leaching method finally selected was fresh water at 80 C., flowing at a rate equivalent to one-fifth of its constant volume per hour.[14–17]

Selection of the Variable Factor

Three parameters presented themselves as possible criteria of relative borer resistance: extent of damage, duration of exposure and level of retention of the treatment. It would seem that relative borer resistance could be determined by holding any two of these factors constant while measuring variations in the third, but such is not the case, for the following reasons:

A. If the retention level is held constant and the length of time required for panels to reach a fixed damage level is used as the index, results will be erratic because the intensity of borer attack varies seasonally.

B. If exposure time is held constant, and the retention level at which panels sustain equal damage is used as the index, it will be necessary to treat large numbers of panels covering a wide range of retentions in order to ensure that comparisons can be made.

The alternative of holding exposure time constant and comparing the damage at a fixed retention level (or within a small range of retentions) appeared to be the selection offering the greatest possible advantage.

Duration of Leaching and Range of Retention

Panels impregnated with whole creosote over a range of retentions of 2-30 pounds per cubic foot were leached for periods of 0, 2, 4, 8, 16 and 32 days. These were then exposed in the ocean to borer attack for six months, after which they were examined and rated for borer damage on a numerical scale from 0-15. The results on panels leached for 0, 4, 16 and 32 days are shown in Figure 1. The others have been omitted to facilitate observation of these, which are the most significant.

The results on unleached panels (0 days leaching) made it apparent that, in order to limit the exposure period required for the test procedure to a reasonable time, it would be necessary to utilize panels impregnated with less than 15 pounds per cubic foot of whole creosote. Leaching for less than 16 days resulted in erratic performance, with poor correlation between creosote concentration and resistance to borer attack. Those panels which had been

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Miller

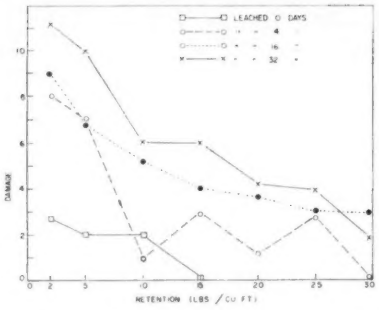

Figure 1—Relationship between damage and retention of whole creosote after several periods of accelerated leaching.

TABLE 1—Ratings for Borer Damage to Panels

Limnoria Damage	Teredid Damage	L or T Rating
None	None	0
Single burrow to 1 colony	1-5 burrows	1
2-3 colonies	6-10 burrows	2
¼-¾ face of panel	11-15 burrows	3
1-1½ faces of panel	16-20 burrows	4
Entire surface attacked.	More than 20 burrows	5

leached for 16 days exhibited a good correlation, and panels in the entire range of retention were damaged within limits which would permit accurate rating and evaluation. In the case of panels leached for longer periods of time, those with the lowest concentrations of creosote were damaged sufficiently to make accurate rating difficult if not impossible.

On the basis of these tests a leaching time of 16 days and a range of retention of 2-13 pounds per cubic foot were selected as standard for the test.

Duration of Exposure to Borer Attack

Marine borer activity in any area varies seasonally. In the tropics especially, each of the various species of borers (some of which are more destructive than others) may predominate at different times of the year. For these reasons, duration of exposure to borer attack in terms of solar time has no finite meaning for a test of this type, because the effect of exposure is dependent upon the borer attack rate, which is not constant. This concept applies to any test of a material under varying natural conditions.

It was reasoned that the extent of damage sustained by a number of panels which were always treated in the same manner could be used as a quantitative measure of borer activity during exposure. However, it was also recognized that in any group of wooden test panels there are usually a small percentage which exhibit abnormally high resistance to attack. Consequently, it was decided that the optimum duration of exposure would be the time required for detectable borer damage to be inflicted upon 90 percent of the panels in a group impregnated with whole creosote over the standard range of retention, and that this should be designated as the "standard borer attack time."

Test Procedure

Preparation of Panels

Clear, edge grain, sapwood (benzidine test) southern pine panels, 5″x1½″x⅛″ were used in these studies. Panels were dried to constant weight (to the nearest 0.1 gm) at 105 C before impregnation. Weight tolerances were established at 8.25 gm ± 0.75 gm.

AWPA Grade 1 creosote, taken from a large supply held in reserve as a standard for future Navy research, was used to impregnate the reference panels, as well as for preparation of all creosote fractions.

The panels were submerged in the whole creosote or fraction to be tested, held at about 75 C in an ordinary hydrogenation bomb, and the desired pressure applied by the admission of nitrogen. The pressure and time of impregnation were varied in order to obtain the desired degree of pickup. After impregnation, the panels were allowed to bleed to constant weight in a desiccator. They were then ready for assay.

Two sets of approximately 40 panels were prepared for each fraction to be tested. They were impregnated over a range of approximately 2-13 pounds per cubic foot. With practice, it was not too difficult to obtain a relatively uniform distribution of retentions covering the entire range, for a given set of panels. Two sets of panels impregnated with whole creosote over the same retention range must be prepared for each group of fraction panel sets which are to be exposed as a unit. As many fraction sets may be prepared as can be facilitated with equipment available, but whole creosoted panel sets must be tested simultaneously, for reference purposes.

Leaching and Exposure

Accelerated leaching of the impregnated panels was carried out in a 25 gallon stainless steel tank which accommodated about 200 panels. An immersion heater was installed at the intake end of the tank, and at both ends, the tank was equipped with thermoregulators and stirrers for maintaining the temperature of the water at 80 C (± 1.0 C). A constant level device at the intake end maintained a fresh water flow rate of 20 liters/hour.

One set of each pair of fraction panel sets and one set of creosoted panels were leached in the tank for 16 days. Following this they were mounted on exposure racks, alongside their corresponding sets of unleached panels. An exposure rack capable of supporting approximately 200 panels can be easily

TABLE 2—Summary of Impregnation Data for Panel Groups Subjected to a Flowing Water Leaching

Group No.	Total Pickup (grams)	Average Impregnation (lb per cu ft)	Accelerated Leaching* (days)	Nonaccelerated Leaching** (months)
1	22.0	14.1	1	0
2	22.1	14.1	2	0
3	22.5	14.4	4	0
4	22.7	14.5	8	0
5	23.1	14.7	12	0
6	23.5	15.0	16	0
7	23.6	15.0	16	3
8	24.0	15.4	16	6
9	24.0	15.4	16	9
10	24.0	15.4	16	12
11	24.2	15.5	0	1
12	24.5	15.7	0	2
13	24.6	15.7	0	4
14	25.0	16.0	0	6
15	25.5	16.3	0	9
16	25.5	16.3	0	12

* Flowing fresh water at 80C.
** Flowing, filtered sea water at ambient temperature.

TABLE 3—Distillation Results on Creosote Remaining in Panels After Various Periods of Leaching with Flowing Water at 80 C

Group No.	Time Leached (days)	Creosote Remaining in Panels (%)	MATERIAL DISTILLING AT 0-270 C (%)	0-270 C (gm)*	270-320 C (%)	270-320 C (gm)	320-360 C (%)	320-360 C (gm)	Residue (%)	Residue (gm)
Control	0	100	16.5	16.5	15.2	15.2	26.1	26.1	41.7	41.7
1	1	59.5**	3.5	2.1	11.9	7.1	27.9	16.6	55.0	32.7
2	2	50.7	5.1	2.6	12.1	6.1	27.4	13.9	54.4	27.6
3	4	44.0	1.6	0.7	16.6	7.3	25.1	11.0	55.6	24.5
4	8	36.6	0.0	0.0	9.4	3.4	29.2	10.7	60.7	22.2
5	12	34.2	1.4	0.5	8.3	2.9	24.6	8.4	62.0	21.2
6	16	30.2	0.0	0.0	7.5	2.3	27.5	8.3	64.4	19.5

* Grams of fractions remaining in panels calculated on the basis of 100 gm creosote originally present.
** Calculated from the curve in Figure 1 because of an unavoidably low recovery.

TABLE 4—Distillation Results on Creosote Remaining in Panels After 16 Days Leaching at 80 C and Subsequent Exposure to Flowing Sea Water at Room Temperature for Various Periods

Group No.	Time Exposed (months)	Creosote Remaining in Panels (%)	MATERIAL DISTILLING AT 0-270 C (%)	0-270 C (gm)*	270-320 C (%)	270-320 C (gm)	320-360 C (%)	320-360 C (gm)	Residue (%)	Residue (gm)
Control	0	100.0	16.5	16.5	15.2	15.2	26.1	26.1	41.7	41.7
7	3	26.3	0.0	0.0	6.4	1.7	23.4	6.1	68.2	17.9
8	6	27.5	0.2	0.0	6.4	1 8	21.7	6.0	67.3	18.5
9	9	27.9	0.2	0.1	6.8	1.9	25.2	7.0	62.5	17.5
10	12	....	0.0	....	5.6	....	25.4	....	66.2	....

* Grams of fractions remaining in panels calculated on the basis of 100 gm of creosote originally present.

TABLE 5—Distillation Results on Creosote Remaining in Panels After Various Periods of Exposure to Flowing Sea Water at Room Temperature

Group No.	Time Exposed (months)	Creosote Remaining in Panels (%)	MATERIAL DISTILLING AT 0-270 C (%)	0-270 C (gm)*	270-320 C (%)	270-320 C (gm)	320-360 C (%)	320-360 C (gm)	Residue (%)	Residue (gm)
Control	0	100	16.5	16.5	15.2	15.2	26.1	26.1	41.7	41.7
11	1	73.1	11.4	8.4	11.9	8.7	29.6	21.7	46.2	33.8
12	2	68.2	10.7	7.3	13.3	9.0	30.5	20.8	44.5	30.1
13	4	61.8	8.6	5.3	14.8	9.1	26.9	16.6	48.6	30.0
14	6	61.6	6.0	3.4	13.9	8.6	27.8	17.1	51.1	31.5
15	9	59.2	4.0	2.4	16.8	10.0	27.5	16.3	51.5	30.5
16	12	59.9	0.0	0.0	13.8	8.3	27.0	16.3	55.9	33.5

* Grams of fractions remining in panels calculated on the basis of 100 gm of creosote originally present.

made from ½ inch square brass bar and bronze sash chain (No. 40). The bar was cut and bolted together to form a rectangular frame 42 inches by 25 inches. Pieces of chain 25 inches long were bolted at 2 inch intervals to the long bars, forming a "ladder." The panels could then be drilled near one end and bolted to the chains with machine screws (No. 6).

The racks were immersed in the ocean at Miami Beach, always at the same fixed level. Fouling was scrubbed from the panels biweekly to facilitate inspection. At the same time, the creosoted reference panels (leached and unleached) were examined carefully after each fouling removal. When 90 percent of the panels in a set of either leached or unleached creosoted panels have been damaged by borers, the creosoted set and its corresponding fraction set(s) were removed from the water and air dried for a few days before final inspection and rating.

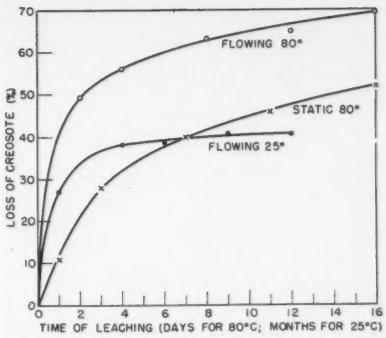

Figure 2—Rate of loss of creosote from wooden panels impregnated to about 15 pounds per cubic foot.

Rating Panels for Borer Damage

Damage to each panel was rated on a numerical scale from 0-5 for *Limnoria* and for teredid damage, according to Table 1.

Limnoria attack occurred more quickly and progressed more rapidly than teredid attack because of the high surface-volume ratio of the panels. Consequently, each panel was given a numerical rating equivalent to L + 2T, to compensate for this ratio. For example, a panel with a *Limnoria* damage of 3 and a teredid damage of 2 would be assigned a final rating of 7.

Evaluation of the Fraction Treatments

The damage ratings for the panels for a "standard" period of exposure may be considered as points on a curve of damage as a function of preservative retention. Experience has shown that such a curve is approximately fitted by an equation of the type.

$$D = AR + B$$

where D = extent of damage in L + 2T units
R = retention level in pounds per cubic foot and A and B are constants.

The damage (D) to be expected at any retention level (R) may be determined by applying the data obtained from the exposure tests to the statistical equation

$$D = \overline{D} + \frac{\overline{RD} - \overline{R}\,\overline{D}}{\overline{R^2} - \overline{R}^2}(R - \overline{R})$$

where a bar over the symbol indicates a mean value. The retention at the midpoint of the retention range is used as the point at which bore resistances of the treatments are compared because at this point the area under the damage versus retention curve is proportional to the damage. By this procedure, the damage to a creosote treatment (D_c) and to each of the fraction treatments (D_f) at the midpoint of the retention range are calculated for the standard borer time. If a factor to reduce creosote and fraction to an equivalent weight basis is applied, the ratio of the calculated damages to creosote and

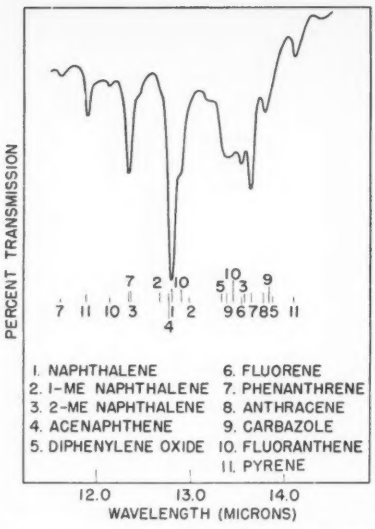

Figure 3—Infrared absorption spectrum of whole creosote extracted from control panels.

fraction is equal to a performance rating, K, as follows:

$$\frac{D_c}{D_f} \times \frac{\%\text{ of fraction in whole creosote}}{100} = K$$

A K value for a fraction is calculated for both leached and unleached sets of panels. This rating is the borer resistance of the fraction treatment relative to that of whole creosote, and is in fact an indication of the total effectiveness of whole creosote which the fraction exhibits. If K is greater than or equal to 1, then the fraction contributes at least its proportionate share toward the effectiveness of whole creosote, and the fraction itself is at least as effective as creosote when present in equal concentration.

The borer resistance (relative to creosote) of the leached fraction treatment is not in itself an indication of the potential service life of the treatment because the equivalent of the leaching treatment in terms of years of service has not been accurately ascertained. However, the ratio of borer resistances (relative to creosote) of the leached and unleached treatments (K_l/K_u) is an indication of the relative abilities of the fraction and creosote to retain their initial effectiveness after the equivalent of long immersion. Thus, if K_l/K_u is greater than 1, the fraction is capable of retaining its effectiveness more efficiently than creosote. If, also, K_u is greater than 1, then the fraction is a better preservative than creosote, and may be expected to provide better service, the extent depending upon the magnitude of the constants.

Mechanism of the Leaching Process

Objective

The diffusion of creosote constituents through wood and out into water is a complicated process which varies with the conditions to which the treated wood is subjected. In order to relate, insofar as practicable, the standard accelerated leaching to natural leaching and better understand and interpret preservative performance data obtained by means of the accelerated leaching procedure, it seemed desirable to study in some detail the changes which occur in an impregnated wooden panel during leaching. This was done by exposing several series of creosoted wooden panels to different degrees of accelerated and nonaccelerated leaching as it is carried out in practice, after which the residual creosote in the panels was examined for changes in composition by means of distillation, infrared spectrophotometry, and molecular weight and oxygen determinations. To supplement data obtained from these experiments, several series of panels were subjected to a modified accelerated leaching procedure which differed from the standard accelerated leaching in that it was conducted under static rather than dynamic (flowing) conditions. The static procedure, of course, only approximated the flowing water procedure, but it offered a quick and convenient way of studying the material leached from the panels. To have obtained this material from a flowing leaching bath would have required a much more elaborate setup.

TABLE 6—Microdistillation of Whole Creosote

Sample Weight (grams)	PERCENT DISTILLING AT				Recovery (%)
	0-270 C	270-320 C	320-360 C	Residue	
6.38	26.5	13.0	23.1	37.3	99.9
6.73	25.7	14.1	23.3	36.1	99.3
8.11	26.1	13.6	22.8	37.3	99.8

Experimental Procedure

Preparation of panels. For this study the same specifications for selection of test panels and creosote were adhered to as in the accelerated leaching test itself. Panels were impregnated as uniformly as practicable with whole creosote in a hydrogenation bomb by submerging them at temperatures of 80-87 C and applying 90 to 100 psi pressure of nitrogen. After impregnation the panels were allowed to bleed to constant weight in a desiccator.

Flowing Leaching procedure. Eighty panels, impregnated over a retention range of 14.1 to 16.3 pounds per cubic foot (4.4 to 5.1 gm per panel), were divided into 16 groups of 5 panels each so that in most groups all of the panels in the group had identical retentions and in no group was the spread of creosote retention more than 0.1 gm. The impregnation data are summarized in Table 2.

The flowing accelerated leaching was carried out by submerging the panels in the tank which was described earlier. The nonaccelerated leaching was accomplished by submerging the panels in a tank of flowing sea water at room temperature. The sea water was filtered to exclude attacking organisms. The leaching schedule is shown in Table 2. All accelerated leachings were commenced simultaneously, as were all the nonaccelerated leachings.

As the leaching periods for the various groups of panels were terminated, the panels of each group were cut into small splints and extracted with toluene in a Soxhlet apparatus for 48 hours. The toluene extract was then shaken several times with a 10 percent solution of sodium carbonate to free it, insofar as possible, from wood resin acids. It was then washed several times with water, dried over anhydrous sodium sulfate, and the solvent removed by distillation. When practically all of the toluene had been removed, methanol was added to the residue and the last traces of toluene removed as the azeotrope. Finally the residue was slowly taken up to 150 C and allowed to remain there for a short time. The percent of material recovered from each group by this method is shown in Tables 3, 4 and 5 (column 3); the rate of loss of creosote from the wood is shown graphically in Figure 2.

Static leaching procedure. The general procedure for the static leaching was as follows: a group of panels, usually 18, was impregnated with creosote as uniformly as practicable to 16.0 (± 0.4) pounds per cubic foot. Panels were then submerged, by weighting, in 10.5 liters of distilled water contained in a 12 liter flask equipped with a reflux condenser, thermometer, heating mantle, and thermoregulator. The water in the flask was maintained at 80 C. At intervals, usually after 1, 3, 7 and 11 days, the panels were removed from the water, washed off with a stream of water from a wash bottle, and resubmerged in fresh water. The leaching water, combined with the washings, was then exhaustively extracted with chloroform. After 16 days of leaching the panels were finally removed from the water and the water extracted as described. The panels were then allowed to dry thoroughly, cut into small splints, and extracted with chloroform in a Soxhelet apparatus for 48 hours. The chloroform extracts for any given group could then be worked up in different ways depending on the results desired. The extracts were finally dried over anhydrous sodium sulfate and the chloroform removed by distillation. The residues were raised slowly to 105 C and maintained at this temperature for a short time. Recoveries were in the order of 98 percent.

Extraction of wood resins. The question of the extraction of wood resins from the panels was not studied exhaustively. Leaching wood in water at 80 C liberates resinous material which can be extracted from the water with organic solvents such as chloroform or toluene.

Eight panels of untreated wood, weighing from 8.0 to 8.4 gm each and having a combined weight of 65.8 gm were subjected to a static leaching experiment as described above in 4.5 liters of distilled water. The leaching water was extracted at intervals with toluene, the toluene removed from the extracts by distillation and the resinous residue weighed. The following results were obtained:

Days Leached	Percent Extracted (Total)
1	0.228
3	0.339
7	0.471
11	0.547
16	0.608

The leached panels were cut into small splints and extracted with toluene to give 0.885 gm of resin or a total resin extraction of 1.94 percent. A set of 24 unleached panels were cut up and extracted to yield 1.28 percent resins. It may be inferred then from these limited experiments that leaching wood in 80 C water makes available a higher percentage of resin. However, whether or not this situation obtains with creosote-impregnated wood is questionable. Some resin also undoubtedly is carried along with the creosote lost during the leaching of impregnated wood. These considerations, coupled with the fact that resins can only be partially eliminated from creosote that is extracted from treated wood, impose certain limitations on analytical data obtained from such materials.

Freeing creosoted-panel extracts of resins by washing with alkali also, unavoidably, frees them of many tar acids. This is perhaps desirable because the study of the differential diffusion of creosote constituents from the wood is then largely confined to the major class of compounds, the hydrocarbons. The tar acids, although minor constituents of creosote, are among the first materials to be lost under natural leaching conditions[1] and the same holds true under conditions of accelerated leaching as will be shown later. Insofar as the percentage recovery of creosote from treated wood is concerned, the presence of small quantities of resin or the absence of small quantities of tar acids may be neglected.

Microdistillation. In order to avoid using an excessively large number of panels, it was necessary to resort to a microdistillation which could handle about 5 to 7 grams of material. Table 6 shows the precision obtainable with three consecutive distillations of whole creosote.

Material balances obtained in the distillations of the panel extracts were, in general, not as good as those obtained from the distillation of whole creosote. This deficiency was attributable to small amounts of residual wood extractives which were present even after the panel extracts had been washed with sodium carbonate solution. Decomposition was evidenced by a characteristic odor and the appearances of smoke and noncondensable vapors.

Infrared analyses. Although there are undoubtedly several hundred compounds in creosote, fewer than 15 contribute to the discrete absorption in the 11-15 μ spectral region. These compounds are the major constituents and account for about one-half of the whole creosote by weight. Since some of the major constituents are present in amounts as low as 1 percent, it is obvious that the residual creosote is comprised of many compounds, each in an amount of less than 1 percent. The spectral effect of such a mixture is like that of a neutral filter (i.e., there is no discrete absorption.) A quantitative analysis can be based on the absorption bands of the major constituents without concern for the background absorption of the residual creosote.

The analysis of an 8 to 12 component mixture in such a narrow spectral region is bound to involve overlapping bands or bands in close proximity which makes the analysis difficult and of limited accuracy. The problem can best be handled by a modified base-line method of analysis where the base line is drawn as if the individual compound under consideration were not present. In case of two components with close or overlapping bands, one of the components usually can be determined at another wave length and a correction applied to determine the other. The choice of the best position for the base line depends upon the experience of the analyst and is essentially a skilled estimate for spectra as complex as these. Analyses are not highly quantitative but, when working with known mixtures, accuracies within $\pm$ 5 percent have been obtained.

Samples were examined in carbon disulfide solution (0.0150 gm/ml) in the 11.0 to 14.5 μ region using a Perkin-Elmer Model 21 Spectrophotometer with a 60 degree sodium chloride prism. Extracts on which hydroxyl content was desired were examined in the 2 to 3μ region in carbon tetrachloride solution (0.01642 gm/ml) in which solvent the samples were not completely soluble.

The spectra of the extracts obtained from the panel groups subjected to varying periods of accelerated leaching are so similar that nothing is gained by presenting all of them. Instead, the spectrum of the whole creosote control, which is typical, is shown in Figure 3.

Results and discussion of leaching mechanism. It can be seen (Figure 2) that panels impregnated to a level of about 15 pounds per cubic foot lose about 70 percent of the original oil when subjected to flowing water leaching at 80 C for 16 days. The rate of loss is rapid at first, about 50 percent being lost after two days. After this period the rate decreases considerably so that the final 20 percent is lost over the remaining 14 days of leaching. When these panels were subsequently subjected to flowing sea water leaching at ambient temperature for one year, no appreciable additional loss of material was noted. A static leaching of panels at 80 C, on the other hand, was not as severe as the flowing hot water leach since it caused only about a 50 percent loss of oil after 16 days (Figure 2).

Panels subjected to a flowing sea water leach lost only about 40 percent of the original oil (Figure 2) after one year, and about 80 percent of this loss occurred during the first two months. From the slight slope of this curve after six months' exposure it is apparent that many years of exposure would be required before panels would sustain a loss of creosote comparable to the loss sustained by panels subjected to the flowing hot water leach for 16 days.

Average molecular weight determinations* on panel groups 1 through 6 (groups subjected to the running hot water leach) indicated that a differential leaching of constituents was occurring, but that the order of magnitude of the change in the average molecular weight of the material remaining in the panels during leaching was not startling (Table 7). The average molecular weight of the material did show a trend, a minimum being observed after about four days of leaching. The molecular weight of the material left in the panels at the latter stages of leaching was greater than whole creosote, as expected. Changes in the average molecular weight of material lost from impregnated panels at progressive intervals of static leaching is shown in Table 8. The trend toward higher average molecular weights of material lost during the latter stages of the leaching process is also evident here. The oxygen contents of the fractions, which because of the sodium carbonate wash would reflect only alkali insoluble phenols or nonacidic oxygen compounds, showed no significant changes.

Because of the relatively rapid loss of tar acids from creosote-impregnated wood immersed in the sea, it was not surprising that static leaching in hot water also caused a relatively rapid depletion of tar acids from the wood. This was shown in a separate static leaching experiement in which the leachings were washed with sodium bicarbonate solution in an attempt to free them of resin acids while leaving the phenolics intact.

* Analyses by Commercial Laboratory.

TABLE 7—Average Molecular Weight and Oxygen Content of Creosote Remaining in Panels After Various Periods of Leaching with Flowing Water at 80 C

Group No.	Time Leached (days)	Average Molecular Weight	Oxygen Content (%)
Control	0	212.0	2.55
1	1	216.8	3.04
2	2	212.5	2.90
3	4	203.0	2.90
4	8	230.9	2.95
5	12	234.3	2.99
6	16	236.6	2.89

TABLE 8—Average Molecular Weight and Oxygen Content of Creosote Leached from Panels After Various Periods of Static Leaching in Water at 80 C

Extract No.	Leaching Period (days)	Average Molecular Weight	Oxygen Content (%)
1	1st	186.3	2.86
2	2nd-3rd	183.0	3.63
3	4th-7th	181.5	2.10
4	8th-11th	195.0	3.65
5	12th-16th	196.3	2.66
Panel residue		206.2	3.54

TABLE 9—Relationship Between Relative Hydroxyl Content and Leaching Time; Static Leaching at 80 C; 16.42 mg/ml CCl_4 Solution

Extract No.	Leaching Period (days)	RELATIVE* HYDROXYL CONTENT			
		Free (2.76μ)		Bonded (2.86μ)	
		Absorbency	%	Absorbency	%
Control	0	0.095	100	0.137	100
1	1st	0.190	200	0.171	125
2	2nd-3rd	0.133	140	0.127	92.8
3	4th-7th	0.023	24.2	0.121	88.3
Panel residue	.....	0.018	19.0	0.109	79.5

* To whole creosote.

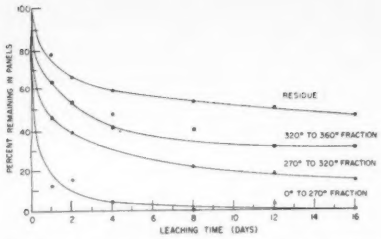

Figure 4—Rate of loss of material of various distillation ranges from creosote-impregnated panels when leached at 80 C in flowing water.

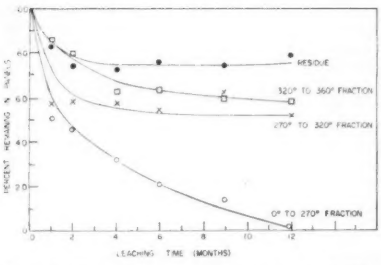

Figure 5—Rate of loss of material of various distillation ranges from creosote-impregnated panels when leached at ambient temperature in flowing water.

Spectrophotometric examination of the progressive leachings revealed two sharp bands arising from hydroxyl group absorption. One, at 2.76 μ, is due to unassociated hydroxyl, and the other at 2.86 μ undoubtedly can be attributed to intramolecularly bonded hydroxyl. Table 9 gives the relative hydroxyl content, free and bonded, of the carbon tetrachloride soluble portion of progressive samples obtained during a static leaching of creosoted panels. In calculating the percentages, the hydroxyl contents of whole creosote were taken at 100 percent. Because essentially all the hydroxyl in creosote occurs as phenolic hydroxyl, it can be seen (Table 9) that there is a relatively rapid and selective leaching of phenolics from the creosoted panels by a static water leaching at 80 C, and the same situation undoubtedly obtains in the running hot water leaching. This loss of phenolics is desirable in an accelerated weathering because the situation is analogous to natural weathering.

The microdistillation data are presented in Tables 3, 4 and 5, both as the percent distilling and the grams of distillation fractions remaining in the panel group after the various leaching or exposure periods. The latter figures were obtained by recalculating the distillation data, assuming as a basis for the calculation that each panel group originally contained 100 gm of creosote.[6] This calculation is accomplished by multiplying the percentage of creosote

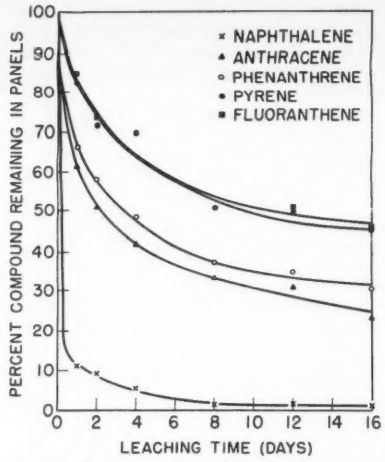

Figure 6—Rate of loss of individual compounds from creosote-impregnated panels when leached at 80 C in flowing water.

remaining in a panel group after the exposure or leaching periods by the percentage distilling in the various temperature ranges. The result is the number of grams of that particular fraction left in the panel group, assuming an original retention of 100 gm of oil. This method of presentation gives a clear picture of the magnitude of the loss of each fraction by leaching or exposure. In order that these data reflect true changes in composition due to leaching and exposure only and not incidental differential losses of constituents incurred through the impregnation and bleeding of panels or through the process of recovery of creosote from the panels, figures are included for creosote extracted from panels which had undergone no leaching or exposure (zero days leaching). A comparison of the distillation data for the zero leaching time (Table 3) with that for whole creosote (Table 6) shows that the physical manipulations of the creosote attendant upon obtaining data from the leaching and exposure of impregnated panels actually caused a change in its composition.

The data in Table 3 show that the impregnated panels exposed to a running hot water leach lost practically all material boiling below 270 C in just two days. After 16 days, about 83 percent of the 270-320 C fraction, 68 percent of the 320 to 360 C fraction and 53 percent of the residue at 360 C had been lost. Very little additional material was lost when these leached panels were subsequently exposed to flowing sea water at ambient temperature for a year (Table 4). Impregnated panels exposed to running sea water at ambient temperature lost essentially everything boiling below 270 C, about 45 percent of the 270-320 C

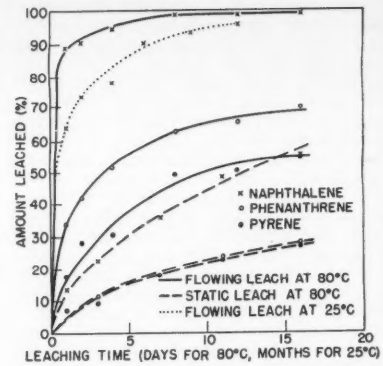

Figure 7—Comparison of rate of loss of individual compounds from creosote-impregnated panels when leached in flowing water and under static conditions.

fraction and about 38 percent of the 320-360 C fraction after one year of leaching (Table 5). Essentially all of the residue lost under these conditions (about one quarter of the original amount present) was lost during the first month of leaching. Whether the leaching was accomplished at 80 C or at ordinary temperature, the data show that the rate of loss of oil from the wood was extremely rapid during the first portion of the leaching period.

It is generally believed that the material making up the distillation residue is both insoluble and nonvolatile. If this point be conceded, for limited exposures, the loss of distillation residue during the first month of the ordinary temperature leaching must have come about by a loss of whole creosote from the panels through mechanical action as distinguished from a purely solubilizing action. The mechanical action may be the washing out of whole creosote from the wood by water or the expressing of creosote due to the swelling of the wood. Because there also occurred during the first month of leaching at ordinary temperature a disproportionation of the yields of the various distillation fractions (see Group 11, percent distilling Table 5) with respect to whole creosote, some differential, solubilizing leaching must have occurred simultaneously with the mechanical leaching. That is, during the first month both types of leaching occurred; after the first month only the solubilizing leaching occurred as can be seen from the essentially constant amount of distillation residue remaining in the panels during the remainder of the year's leaching. The loss of whole creosote undoubtedly occurs also during the initial stages of the accelerated leaching; in this case thermal expansion of creosote probably plays a part.

TABLE 10—Percentage of Distillation Fraction Remaining in Panels

Fraction	Percent Remaining in Panels	
	80 C Leach (16 days)	Sea Water Leach (12 months)
0-270 C	0	0
270-320 C	17	55
320-360 C	32	62
Residue	47	75

TABLE 11—Distillation Results on Material Lost from Panels During Various Periods of Static Water Leaching at 80 C

Extract No.	Leaching Period (days)	Creosote Remaining in Panels (%)	MATERIAL DISTILLING AT							
			0-270 C		270-320 C		320-360 C		Residue	
			(%)	(gm)*	(%)	(gm)	(%)	(gm)	(%)	(gm)
Control	0	....	26.3	....	13.6	....	23.1	...	36.9	....
1	1st	....	29.7	....	12.2	....	21.2	....	33.5	....
3	4th-7th	....	31.7	....	9.9	....	23.0	....	32.0	....
5	12th-16th	....	56.5	....	12.5	....	12.8	....	17.9	....
Panel residue	.....	51.8	5.5	2.9	13.3	6.9	29.2	15.1	48.1	24.9

* Grams of fractions remaining in panels calculated on the basis on 100 gm originally present.

Validity of the comparison of leaching to exposure. The standard accelerated leaching procedure described in this paper attempts to telescope many years of natural leaching into a short period of time. It is at least a means of inducing a differential depletion of the creosote in a manner which is comparable to that which takes place in service. This is indicated by the somewhat remarkable similarity of the families of curves (Figures 4, 5) obtained when the percentages of the various distillation fractions remaining in the panel groups (which had been originally impregnated with whole creosote and leaching in flowing water at 80 C (Figure 4) or in sea water at ambient temperature (Figure 5)) is calculated from the data in Tables 3 and 5 and plotted against the time of leaching. A less dramatic but more convenient (for precision) comparison may be shown by Table 10.

It can be seen that the order in which constituents are leached from wood in water at 80 C is identical with that in sea water at ambient temperature. That there is an actual long-term equivalence of the accelerated leaching procedure and natural exposure is suggested when one notes the agreement between the amount of the various distillation fractions remaining in the wood after nine months of leaching at ordinary temperature and the amounts remaining after one day of accelerated leaching (Figures 4 and 5). An extrapolation, based on this correspondence, would equate 16 days of accelerated leaching with 12 years of leaching at ordinary temperature. Additional experiments might vindicate the extrapolation.

The loss of residue from the wood during accelerated leaching is not considered inconsistent with the earlier statement concerning its nonvolatility and insolubility. It is probably true that for all practical purposes the higher boiling constituents of creosote are insoluble and nonvolatile when considering short exposures. For long exposures, however, there must be some loss of high-boiling material, other than that lost initially as whole creosote, as leaching continues years after the depletion of the lower boiling constituents.

Static leaching of creosoted panels at 80 C is a less severe treatment than the running water leaching as can be seen from the curves of Figure 2 and a comparison of the data in Table 11 with that presented in Table 3. The material leached out on the first day had a distillation pattern similar to that of whole creosote and probably consisted largely of whole creosote which had been expelled from the panels although some disproportionation is evident. Differential leaching of constituents gradually predominates, however, as can be seen from the percentages of the 0-270 C fraction and residue in the later stages of leaching. The weight distribution of the various distillation fractions remaining in the panels after 16 days of static leaching (panel residue) is similar to that of the material remaining in the panels after one day of flowing water leaching, assuming in both cases an original creosote retention of 100 gm (compare Tables 3 and 11). This would indicate that a static leaching at 80 C for 16 days is about equivalent to a flowing water leaching at 80 C of one day.

The pattern of the loss of material in the various distillation ranges caused by the different types of leaching is in good agreement with the loss of individual compounds as determined by the spectrophotometric analyses. The curves of Figure 6 show that a flowing water leaching at 80 C rapidly depletes the creosote-impregnated panel of naphthalene which is a major constituent of the low-boiling fraction. The higher boiling constituents, anthracene, phenanthrene, pyrene, and fluoranthene, are also rather rapidly lost at first from the wood. After the initial rapid loss their rate of depletion decreases although a continued loss is evident throughout the entire 16-day leaching period. (Figure 6.) Leaching at ordinary temperature, on the other hand, causes a less rapid depletion of naphthalene (Figure 7); the rate of diffusion of the higher homologs apparently was too slow to be determined under the conditions of the experiment.

A comparison of the rate of leaching of naphthalene, phenanthrene, and pyrene under static and flowing leaching conditions at 80 C is shown in Figure 7. Flowing water obviously hastens the leaching of compounds from the wood.

Summary

1. A method is presented for comparing the marine borer resistance of creosoted wood with that of wood treated with fractions of creosote obtained by distillation, solvent extraction, etc. The test method is accelerated by the expedients of:

a. The use of test panels of small size with a high surface-volume ratio.

b. Leaching replicates of these panels at 80 C in flowing fresh water for 16 days, prior to exposure to borer attack.

2. The mechanism of leaching in sea water and in the accelerated leaching medium was studied by subjecting creosoted panels to the following treatments:

a. Leaching at 80 C in flowing fresh water (standard procedure).

b. Leaching at 80 C in flowing fresh water for 16 days followed by leaching in sea water at ordinary temperature.

c. Leaching in sea water at ordinary temperature.

d. Leaching at 80 C in still fresh water.

3. The rate of leaching of material from the panels and the change in composition of the residual or leached creosote brought about by the differential diffusion of constituents from the wood were studied. Changes in composition were studied by means of distillation, average molecular weight and oxygen determinations, and infrared spectrophotometry.

4. The standard accelerated leaching of creosoted panels brings about a differential loss of creosote constituents comparable to the loss of constituents occurring during leaching in sea water, but at a more rapid rate.

5. Leaching of panels at the same temperature as that in the standard treatment but under static conditions is a much milder treatment. The same materials are lost from the wood but the quantity of material is less and the rate of loss is lower.

6. The material remaining in creosoted panels after nine months of leaching at ordinary temperature had almost the same distillation pattern as the material remaining after one day of leaching at 80 C, both leachings being conducted in flowing water. Upon extrapolation, this correspondence equates 16 days of accelerated leaching with 12 years of leaching at ordinary temperature.

7. Infrared spectroscopy can be used to good advantage in analyzing creosote fractions qualitatively and quantitatively for major constituents.

8. The ease with which some of the major creosote constituents are leached from wood by the standard leaching procedure as determined by infrared analysis is as follows:
naphthalene $>>$ anathracene $=$ phenanthrene $>$ fluoranthene $=$ pyrene

Acknowledgment

The authors are indebted to the various members of the staffs of the Naval Research Laboratory and The Marine Laboratory who provided valuable assistance. Grateful acknowledgement also is due the Navy Department's Bureau of Yards and Docks and the Office of Naval Research, under whose sponsorship the work was carried out.

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Accelerated Condensation Corrosion Test For Evaluating Rust Preventives*

By E. A. DIEMAN and J. W. GAYNOR

Abstract

A new test—the Accelerated Condensation Corrosion Test—has been developed for quality control of rust preventives. The test features short testing time and good precision. Short testing time is obtained by accelerated condensation on steel test panels. Good precision is obtained by close control of condensation and by use of a new panel-preparation procedure in which the panels are water-treated. Testing times are 1/20 to 1/50 of those obtained in JAN-H-792 humidity-cabinet tests. Precision with the new test is about three times as good as with the older test. 2.3.2

Introduction

THE HUMIDITY cabinet and test procedure covered by JAN-H-792 specification[1] is widely used for laboratory evaluation of rust preventives. In this test, steel panels coated with rust preventive are exposed to a humid atmosphere at 120 F and are periodically examined for initial rusting. There are two objections to the test: long testing time, and poor precision. The long testing time is objectionable to manufacturers of rust preventives because of hold-up of shipments pending quality approval. The poor precision makes evaluations subject to question.

The long test time is due to low condensation on the panels. The JAN specification states that the test "is intended to provide . . . continuous condensation on the test panels," but data obtained in the authors' laboratory show that this condition does not exist. Condensate collected in pans placed under panels during test operation ranged from none to 5 ml per day per panel. Until recently, no test methods have been reported that provide any appreciable reduction in testing time. However, a recent paper by Roden[2] reports on a closed-cell test with testing times about 1/5 those for the JAN test; rusting is accelerated by increased condensation on the panels, obtained by keeping the panels at a lower temperature than the surrounding atmosphere.

The poor precision of the JAN test has been under study in several laboratories for a number of years. Most investigations have centered around different techniques of panel preparation. None gave any significant improvement in precision. Slight to moderate improvement in precision is reported for Roden's closed-cell test and for cloud-chamber[3] and fog-chamber[4] tests.

Studies at this laboratory have been directed toward development of a short test, with good precision, suitable as a quality-control test. A test meeting this objective has been developed and has been named the Accelerated Condensation Corrosion Test, or ACCT. Short testing time is due to accelerated condensation; good precision is due largely to close control of condensation and to the use of a new panel-preparation procedure.

Dieman Gaynor

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J. WILLIAM GAYNOR—Group leader in charge of research on industrial lubricants, he joined the research department of Standard Oil Co. (Indiana) Whiting, Ind., in 1937. He has a BA from Yankton College and an MS in organic chemistry from the University of Michigan. He is a member of ACS and ASLE.

Apparatus

The basic features of the test are shown in the cross-section drawing, Figure 1. Water coolant from an external tank is pumped into a reservoir mounted on the rotating stage of a JAN humidity cabinet. The coolant flows, by gravity, from the reservoir to hollow box-type panels suspended on the rotating stage. The panels are thus maintained at a lower temperature than the surrounding humid atmosphere and accelerated condensation is obtained. Coolant overflows from the panels into a trough mounted on the inside wall of the cabinet and is returned by gravity to the tank via a manifold and tubing system.

The tank holds five gallons and is fitted with suitable heaters and controls to maintain the desired temperature. A pump with a minimum delivery capacity of 1.5 gallons per minute is connected to it.

The reservoir, with several panels in place on the rotating stage, is shown in Figure 2. The reservoir is of stainless steel, 2½ inches deep and 6 inches in diameter. It is mounted in the center of the rotating stage. For receiving coolant, a 1½-inch tube projects from the top, and through the cloth cover of the cabinet. Fifteen stainless-steel spouts, ¼ inch in diameter and 1 inch long, extend outward from the bottom edge of the reservoir. Rubber tubing connects them to the panels on the stage.

A box-type panel is shown in Figure 3. The test surface is a 2 x 4 x ⅛-inch plate of 1020 steel which is soldered to the open side of a 1½ x 3½ x ½-inch stainless-steel box. At the ends of a long edge of the box, inlet and outlet tubes of ¼-inch copper tubing project upward and are formed to support the panel on the stage. Coolant flow through properly constructed panels is 350 to 400 ml per minute per panel under test conditions.

A two-unit ACCT assembly, with control board, is shown in Figure 4. The front of each cabinet is fitted with a 6 x 15-inch window, positioned to permit observation of the panels. An internal windshield wiper and an external spotlight facilitate viewing.

Procedure

The 1020 steel surface of the panel is sandblasted at a pressure of 100 psi. Fresh sand meeting US Army MIL-L-21260 specification is used. The test surface is sandblasted in two directions, horizontal and vertical, with the surface about 1 inch from the nozzle of the blaster. After sandblasting, the panels are rapped sharply against a firm surface to remove adhering sand and are immediately (1) dipped in distilled water for five seconds, (2) dipped, with agitation, in chemically pure methanol for five seconds, (3) air-dried for 15 seconds, (4) dipped in the rust preventive for one minute, and (5) allowed to drain for 16 to 18 hours at room temperature. Three panels are so prepared with each rust preventive to be tested.

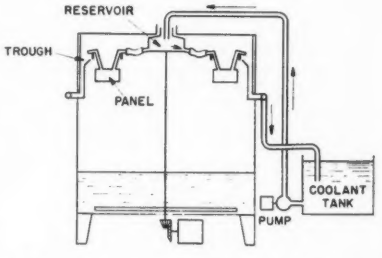

Figure 1—Cross section of Accelerated Condensation Corrosion Test apparatus.

★ Submitted for publication November 12, 1957. A paper presented at a meeting of the North Central Region, National Association of Corrosion Engineers, Chicago, Illinois, October 2-4, 1957, and at the 13th Annual Meeting of the ASLE, Cleveland, Ohio, April 22, 1958.

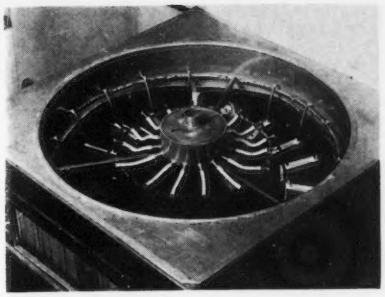

Figure 2—Reservoir with several panels in place on stage.

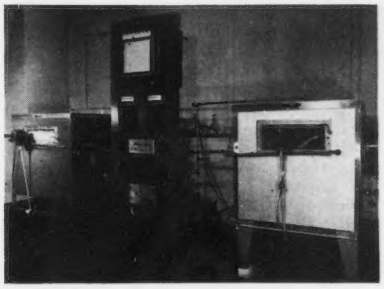

Figure 4—Two-unit ACCT assembly.

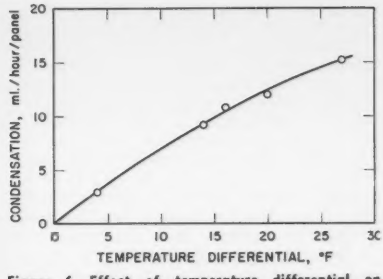

Figure 6—Effect of temperature differential on condensation.

Figure 3—Box-type panel.

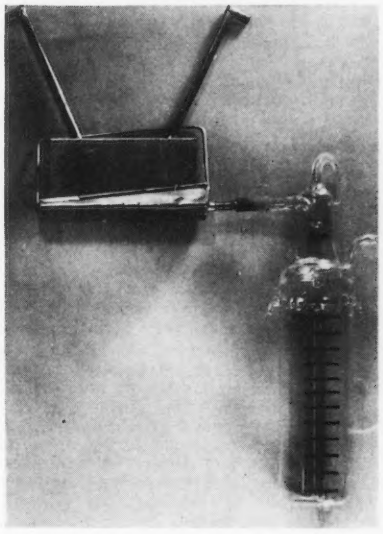

Figure 5—Condensate-measuring device.

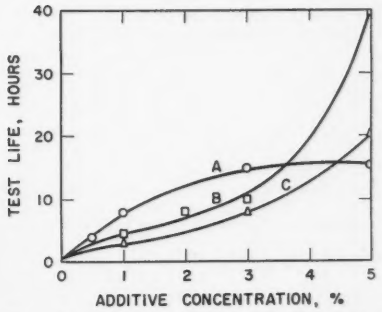

Figure 7—Effect of additives on test life. Additive A is an alcohol ester, B is a petroleum sulfonate and C is marketed as "a mixture of oxygenated hydrocarbons."

Fifteen panels are always present on the rotating stage of the cabinet to maintain constant operating conditions. Three of the panels serve to check uniformity of operating conditions; two are treated with a product of known performance, the other is an all-stainless-steel "blank" panel under which is placed a condensate-measuring device such as shown in Figure 5. Any of the remaining 12 spaces not needed for testing are fitted with stainless-steel blanks.

The test is operated under conditions shown in Table 1; included, for comparison, are JAN operating conditions. In both tests the stage is rotated at ⅓ rpm, slowly enough that the direction the panels face has no effect on test results.

The panels are viewed through the window of the cabinet for corrosion at ½-hour intervals. A panel is rated "fail" when stain or rust is first observed, providing the amount observed at the next inspection is greater; stain or rust that does not increase is attributed to an abnormal panel surface and is discounted. The hours-to-fail values obtained on the three panels in a test are averaged, and the resulting single value is reported as the test life of the oil.

Test Development and Results

A rust preventive having an average test life of about 200 hours in the JAN test was used in the development of the ACCT.

Initial studies involved determining the amount of condensation obtained with different coolant temperatures but with the cabinet water-bath maintained at 130 F. The data obtained are presented graphically in Figure 6 as condensation versus temperature differential between the cabinet atmosphere and the coolant. The relatively high condensation rate of 12 ml per hour per panel, obtained with 90 F coolant and a temperature differential of 20 F, was selected for study.

A conventional panel-preparation procedure used in JAN tests at this laboratory was used in initial investigations. This procedure involves, in order, sandblasting, naphtha rinsing, alcohol rinsing, drying, and application of rust preventive. A satisfactorily low testing time was obtained, but precision was not satisfactory. Water treatment of panels was investigated on the premise that poor precision might be due to non-uniform surfaces caused by variable absorption of moisture from the air after sandblasting and before application of rust preventive. Precision improved markedly, and the water-dip treatment was adopted.

A comparison of test time and precision with the conventional and the water-dip procedures is shown in Table

TABLE 1—Operating Conditions

	ACCT		JAN	
	Controlled	Resulting	Controlled	Resulting
Cabinet Water Bath, °F.	130 ± 1.0	.....	.....	130
Panel Coolant Water, °F.	90 ± 0.5	.....	.....	.....
Aeration, cu ft/hr	31.2 ± 1.0	.....	31.2 ± 4.0	.....
Coolant Circulation, gal/min	1.5 ± 0.1	.....	.....	.....
Cabinet Atmosphere, °F.	.....	110	120 ± 2.0	.....
Temperature Differential, °F*	.....	20	.....	(0)
Condensation, ml/hr/panel	.....	12 ± 0.7	.....	(none to 0.2)

* Between cabinet atmosphere and panel coolant water.

TABLE 2—Effect of Panel Preparation on Test Time and Precision

	Number of Tests	TEST LIFE, HOURS		Standard Deviation, Percent
		Range	Average	
Conventional	10	2–11	6	45
Water-Treated	15	10–15	13	13

TABLE 3—Comparison of Test Time and Precision

	Number of Tests	TEST LIFE, HOURS		Standard Deviation, Percent
		Range	Average	
JAN	6	98–344	224	40
ACCT	15	10–15	13	13

2. Repeatability refers to the variability of test life values and is expressed as standard deviation, percent, in accordance with ASTM recommendations.[5] A longer but satisfactorily rapid testing time resulted with the water-treated panels. Repeatability with the water-dip treatment is about three times as good as with conventionally prepared panels. The significance of the data on the water-treated panels is strengthened by the fact that the results are from tests run over a period of more than a year.

A comparison of test time and precision of the ACCT and the JAN test is shown in Table 3. The test life data reported for the JAN tests were obtained by averaging the hours-to-failure values for each of the five panels in a test. Testing time in the ACCT is about 1/20 that required in the JAN test; precision is about three times as good. Precision in the JAN probably would be improved with water-treated panels, but the objectionably long testing time would still exist.

Other rust preventives have been tested in the ACCT, with test life results ranging from 3 to 40 hours. Testing times have ranged from 1/20 to 1/50 of those in JAN tests. Repeatability has been of the same order of magnitude as with the product used in test development. Tests also have been run on oils containing various amounts of additives. Curves of test life versus concentration for different additives may differ markedly, as shown by the data for three commercial rust-preventive additives in Figure 7. Additive A is an alcohol ester, B is a petroleum sulfonate and C is marketed as "a mixture of oxygenated hydrocarbons."

The standard ACCT, with a condensation rate of 12 ml per hour, meets the short testing time and good precision needed for a quality-control test. Further test work is required to determine correlation of ACCT evaluations with service performance. Tests at a lower condensation rate may be desirable in such correlation studies.

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Any discussions of this article not published above will appear in the December, 1958 issue

DISCUSSIONS

Chloride and Caustic Stress Corrosion of Austenitic Stainless Steel in Hot Water and Steam by W. Lee Williams. Corrosion, Vol. 13, No. 8, 539t-545t, (1957) Aug.

Comments by C. Edeleanu and P. P. Snowden, Brown-Firth Research Laboratories, Sheffield, England.

This clear and practical appraisal of the stress corrosion position in the use of austenitic steels with high temperature water will be of great value to engineers concerned with the design and operation of such a plant.

The paper has been of special interest here because of the close similarity of conclusions reached from our own study of effects of salt and alkali contamination under such conditions. Details of much of this work have been published recently[1] and need not be further discussed here; but one or two points may usefully be noted.

Reference is made in the present paper to the rapidity of failure under conducive conditions. Using a "dewpoint" test involving a chloride contaminated specimen cooled from superheat through the dewpoint of 1500 lb steam at 315C (599F), we have failure through .045 inch thickness in a few minutes with 29,000 psi stress. With sodium chloride, rapidity of attack falls off very quickly above the dew point to a penetration of .009 inch in 48 hours at 330C (636F) and much slower attack at still higher temperatures. With caustic soda the position is different, passing from the "damp" to the molten condition around 318C with rapid attack and no oxygen requirement.

It is of primary importance to understand more fully and quantitatively conditions governing the separation of caustic alkali from boiler waters and the possibilities of inhibition. We have tests in progress or planned, with inhibitors operating under "dewpoint" and crevice conditions as well as tests with solutions of known concentrations, both for sodium chloride and caustic soda. We shall look forward with keen interest to the results of the current tests scheduled by Lee Williams in the present paper.

Reference

1. C. Edeleanu and P. P. Snowden. Stress Corrosion of Austenitic Stainless Steels in Steam and Hot-water Systems. *Journal of the Iron and Steel Institute*, **186**, 406-422 (1957) August.

Corrosion and Adsorption Studies Using Sulfonate Inhibitors by A. H. Roebuck, P. L. Gant, O. L. Riggs and J. D. Sudbury. Corrosion, Vol. 13, No. 11, 733t-738t, (1957) Nov.

Comments by S. L. Chisholm, Naval Air Station, San Diego, California:

Corrosion studies using sulfonate inhibitors also have been made by evaluating the electrical polarization of a coated iron wire or sheet steel electrode immersed in water. If coated with an alkali or alkaline earth petroleum sulfonate alone, as by dip coating from a volatile solvent, the coating is hydrophilic and disintegrates into the water. No effective polarization or protection results, unless the water contains a few percent of alcohol to sufficiently increase the sulfonate solubility.

By contrast, if a sensible proportion of lubricating oil is present, the film becomes sufficiently hydrophobic to withstand disintegration in water, and the steel surface becomes polarized and protected. Such films are oily and drain, in this case upward to the liquid-air-interface. By a combination, in a mutual volatile solvent, of such a petroleum sulfonate and a suitable amine salt, and by dipping or spraying and drying, a fixed non-draining thin film is produced. This film is strongly hydrophobic, and persists, polarizes and protects the surface.

Metathesis to an amine sulfonate is fully completed by access of moisture or the aqueous extraction from the film of the resulting inorganic salt. Such films, locally termed Siponols, have very interesting and useful properties when generated by alkyl amine salts with pronounced hydrocarbon substitutents. An example of this is dicyclohexyl amine, used as the nitrite, and dissolved together with a sodium petroleum sulfonate in isopropyl alcohol.

The improved protection of the amine sulfonates also may result in part from a more effective Fe-N bonding. Siponol films have been employed usefully on anti-friction bearings and other bare steel working surfaces and tools during processing, storage and installation. Such films are not impaired by intimate overwraps. In fact, even vigorous wiping leaves a smear film with very effective residual protection—so much so that small tools, such as pocket steel rules in constant use, resist corrosion for a very considerable period. Siponol films do not require removal for installation, lubrication, or use, and the solutions are very effective fingerprint neutralizers.

A rather wide range of alkyl amines, as salts, such as the carbamate, benzoate, etc., have been reacted with various commercially purified petroleum sulfonates to produce results comparable with the example cited. The Siponol film also provides significant boundary lubrication for working surfaces.

The term "Siponol" signifies that isopropyl alcohol, or its blends, was the earliest and most useful common solvent employed. Stoichiometric proportions of amine salt and of sulfonate do not appear essential to the production of useful results. Protection by a free amine does not appear to be comparable unless the resulting pH exceeds about 10. Thus the inclusion of a free amine, as a hydrobromic acid neutralizing agent, in the sulfonate-oil preservative compounds used for internal combustion engines for nearly 15 years, probably did not enhance significantly the sulfonate protection, as such. Sulfonates now used for this purpose have been supplanted largely by ash-free non-organic inhibitor compounds; however, amine sulfonates also are ash-free.

Reply by A. H. Roebuck.

The comments made by Mr. Chisholm are pertinent and interesting. Our experiments substantiate his findings on the effect of oil in sulfonates. Experiments carried out on sulfonates from which the oil had carefully been removed indicated a large diminution in corrosion inhibition characteristics. Likewise, sulfonates dispersed in a light volatile hydrocarbon were found to be effective inhibitors when applied to tools and other fine machine parts as a spray. These parts were not impaired for immediate use by the sulfonates which acted as a lubricant.

High-Temperature Hydrogen Sulfide Corrosion Of Stainless Steels—A Contribution to the Work of NACE Technical Unit Committee T-8 On Refinery Industry Corrosion, By E. B. Backensto, R. E. Drew, J. E. Prior and J. W. Sjoberg. Corrosion, Vol. 14, No. 1, 27t-31t, (1958) Jan.

Questions by Frank J. Bruns, Sinclair Research Laboratories, Inc., Harvey, Illinois:

What was the method used for determining corrosion rates? How were specimens cleaned? Were manganese stainless steels also subjected to hydrochloric acid?

Reply by E. B. Backensto:

All corrosion rates were calculated from weight loss data after cleaning with inhibited HCl as described in an earlier paper (**Corrosion**, Vol. 12, No. 5, 237t (1956) May.)

Question by F. B. Hamel, Standard Oil Company of Ohio, Cleveland, Ohio:

Have you checked the grain structure and size for wrought, weld and cast materials?

Reply by E. B. Backensto:

Yes, we have checked the materials metallographically. The structures were normal for wrought, weld and cast materials.

Prevention of Localized Corrosion in Sulfuric Acid Handling Equipment by G. A. Nelson. Corrosion, Vol. 14, No. 3, 145t-149t, (1958) Mar.

Discussion by F. L. LaQue, The International Nickel Co., New York, New York:

It would be interesting if the author could reconcile the difference between

his observations and those of Manuel[1], particularly with reference to the criticality of the environment as related to benefits observed by Manuel when the pearlite existed in a lamellar form as against the spheroidal state. On the basis of Nelson's observations it might be concluded that iron substantially free from carbon would not show the effects of the heat of welding that Nelson described. On the other hand, in Manuel's experiments a substantial amount of carbon was found to be desirable and, under certain conditions, iron of very low carbon content performed very poorly.

Reference

1. *Corrosion*, 3, No. 9, 415-431 (1947) Sep.

Reply by G. A. Nelson

In an endeavor to reconcile the difference between the results described in this paper and those observed by Manuel, a series of test samples was prepared and exposed in a sulfuric acid tank.

For the purpose, samples of iron and steel sheets were obtained. Carbon contents were as follows:

	Carbon
ARMCO Iron	0.04%
Vacuum Melted Iron	0.01
Vacuum Melted Steel	0.15

Samples were prepared for testing as follows:

1. Samples of each metal, approximately 2 inch x 4 inch x 16 ga were welded to each other using the heliarc method and using no filler metal.

2. Samples prepared as in (1) and normalized at 1650F.

All samples were sandblasted free of scale before testing. The samples were exposed in a storage tank for 105 days to the action of 67 percent H_2SO_4 at a temperature of 70-80F.

After the exposure period the samples of low carbon irons were free from accelerated grooving action near the welds or other heat affected areas. The samples of steel, on the other hand, showed grooving effects in the "as welded" samples in similar heat affected areas. After normalizing, the grooving effects on the steel samples were absent.

The general corrosion rate of the low carbon iron samples was higher than the steel samples being 68 mils per year as contrasted to 50 mils per year for the steel.

It appears from these results that a certain amount of carbon is necessary in steel in order to produce structures from heating which are susceptible to accelerated corrosion in certain media. This is in agreement with the findings of this paper. On the other hand, in agreement with Manuel's experiments, carbon free iron corroded in the particular medium (67 percent H_2SO_4) at a higher rate than steel.

Discussions to technical articles appear in the June and December issues only when they do not immediately follow the article to which they pertain. Discussions received from December through May will appear in the June issue and those from June through November in the December issue.

DISCUSSIONS ON TECHNICAL ARTICLES ARE SOLICITED

Discussions on technical articles published in Corrosion will be accepted for review without invitation. Discussions must be constructive, accompanied by full substantiation of fact in the form of tables, graphs or other representative data and be submitted in three typewritten copies.

Authors of discussions are asked to supply one copy of figures suitable for reproduction and will be sent on request a copy of the NACE Outline for the Preparation and Presentation of Papers.

Discussions will be reviewed by the editor of Corrosion and will be sent to the author of the paper discussed for his replies, if any. Publication will be in the Technical Section with full credit to the authors together with replies. Discussions to papers presented at meetings of the association may be submitted in writing at the time of presentation or later by mail to the editorial offices of Corrosion, 1061 M & M Bldg., Houston 2, Texas.

Three New Coatings Task Groups Are Formed

Four Societies Cooperate On Plastics Numbering

A number system for classifying plastics, a major project on which four other technical societies are working with NACE Unit Committee T-5D, Plastic Materials of Construction, is the main objective of the committee. Members of T-5D were told the other societies, ASTM, SPI, SPE and ASA, were cooperating with NACE. The committee met in San Francisco during the NACE 14th Annual Conference.

Several bottlenecks have developed in establishing the system, and significant changes will have to be made from the original plan of a system based on chemical products. The numbering system is devoted to generic types. Subcommittees organized on these same lines will bring together members of like interests and talents, it was felt.

A questionnaire will be sent to each member of T-5D in an effort to determine the way in which the members can best serve the interests of the committee. Reorganization will be handled by the committee officers.

Also presented at the meeting was a report on the use of plastics in the chemical processes industries. Copies of the report were distributed. After discussion, several constructive criticisms and corrections were made and changes will be made in the report.

Vice Chairman R. E. Gackenbach, American Cyanamid Co. presided at the meeting.

Dellenbach

Russell

Heverly

Newly elected executives who will guide the Southern Ontario Committee on Electrolysis are shown here. From left to right they are: K. G. Dellenbach, Imperial Oil Ltd., Sarnia Products Pipe Line, chairman; G. I. Russell, G. I. Russell & Company Ltd., vice-chairman; L. F. Heverly, Trans-Canada Pipe Lines, Ltd., secretary treasurer. The election was conducted at the recent annual meeting. The committee is affiliated with Unit Committee T-7, Canadian Region Corrosion Coordinating Committee.

Scope of Sulfuric Acid Committee To Be Narrowed

A change in the title of Unit Committee T-5A to better describe the broadness of objectives of the committee was approved by the Technical Practices Committee in its meeting at the Fairmont Hotel in San Francisco, March 20. The new title is Corrosion in Chemical Processes. The old title, Chemical Manufacturing Industry gave only a partial indication of the interests of the committee.

In the meeting of the committee March 17, most of the time was devoted to hearing reports and discussing business of six task groups. A special point was made that all task groups should remain active and find ways to continue aid to industry. A suggestion that each task group publicize in CORROSION a request for problems which need answering, met with favorable reaction.

A decision to narrow the work of task group T-5A-1 sulfuric acid, was made. It had been working in a broad field, but it was thought more benefit

(Continued on Page 66)

Criteria for Cathodic Protection Is New Title

The Technical Practices Committee approved a change in title and scope of Unit Committee T-2C at its meeting in San Francisco, March 20. New title for the committee is: Criteria for Cathodic Protection.

The following statement of the objectives of the committee was approved as follows: Scope: To examine the basic criteria that can be used for determining adequacy of cathodic protection through examination of coupons, potential and current density surveys, and various other measurements; and by surveying and assembling practices of operating organizations and engineers and their criteria for cathodic protection. To study the possible consequences of over protection; and to promote research and technical papers on criteria for cathodic protection.

Wax Type Coatings Unit

A new unit committee designated T-2L Wax-type Pipe Coatings and Component Wrappers has been approved to investigate the use of these kinds of coatings and wrappers for underground pipe lines—wrapped systems. Approval of formation of the committee was voted by the Technical Practices Committee in its March 20 meeting in San Francisco.

Three Reports Are Discussed at Session of T-6A

Formation of three new task groups, a project to edit and publish reports, a decision to submit a report on coal tar coatings for publication by NACE and discussion of three reports were main points of a March 19 meeting of Unit Committee T-6A Organic Coatings and Linings for Resistance to Chemical Corrosion. The meeting was held during the 14th Annual Conference in San Francisco.

The three new task groups are T-6A-7 Thermosetting Coal Tar Coatings, W. E. Kemp Koppers Company, chairman; T-6A-20 Plastisols, Otto Fenner, Monsanto Chemical Co., chairman; and T-6A-6 Neoprene, John R. Galloway, E. I. duPont de Nemours & Co., chairman.

A report of T-6A-20 will be issued as an addendum to the report on vinyl linings.

A report on coal tar coatings by C. U. Pittman, Koppers Co., Inc., Tar Products Div., was summarized by John Richardson, Amercoat Corp. It includes suggestions received from members. After discussion, it was voted to submit the report for publication.

Combining and editing all reports so they could be published in a bound volume was a project established by the members attending the meeting. No chairman was selected for the project.

A report on Hypalon coatings was presented by J. R. Galloway, E. I. duPont de Nemours & Co., Inc. He pointed out that Hypalon can be applied as a paint-type coating or as uncured sheet, using properly formulated primers and adhesives.

Concerning phenolic coatings, Forest Baskett, Sheet Metal Engineers, Inc., told the group the report is now limited to pure phenolic and high temperature baked coatings and that it is ready for circulation to the committee members for comments.

L. S. Van Delinder, Union Carbide Chemicals Co., summarized his report on polyethylene. Suggestions were made that it should be said that only low density polyethylene was covered. The report will be revised and recirculated to members.

R. McFarland, Jr., Hills-McCanna Co. reported on rubber linings. He suggested the report be restricted to hard rubber linings in the Shore D range of hardness and not include "ebonized" rubber.

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During 1957 NACE distributed more than 226,000 copies of its technical committee reports.

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In addition to those held at the annual national NACE meeting, 36 technical committee meetings were held at regional sessions during 1957.

T-4 Grounding Task Groups Are Merged

Two task groups, T-4A-1 and T-4A-2 have merged into one task group, T-4A-3 Methods and Materials for Grounding to obtain better integration of reports. The action was taken at the meeting of Unit Committee T-4A, Effects of Electrical Grounding on Corrosion during the NACE 14th Annual Conference in San Francisco. Two reports, one from T-4A-1 and one from T-4A-2 were given at the meeting.

The T-4A-1 report by V. B. Pike, Bell Telephone Laboratories, gave reasons for grounding electrical circuits and explained the good and bad points on various grounding systems and protective metals. The basic concept is to have the metal objects within a building so interconnected with respect to each other and ground that there will be minimum possibility for dangerous potential to develop among them.

In general, the best means of grounding electrical circuits and equipment is to ground to public water supply pipes. However, it was developed in discussion that some water companies are now using transite pipe and insulating joints which lessen effectiveness of the ground, and in some instances refuse to authorize electrical connections to their piping. In the discussion, other general opinions indicated that corrosion control practices and use of new materials are reducing the effectiveness of piping systems as electrical grounds; that water and gas companies should not be expected to be responsible for providing good electrical grounds through their system; and that it is becoming more necessary for electric utilities to provide adequate grounds of their own without reliance on piping systems.

Other methods of grounding suggested in the report were: local piping systems, building frames, well casings, driven rods, driven pipes, buried metal plates, buried lengths of metal such as railroad rail, stranded cable or ribbon and ship hulls.

Metals that have been used most successfully in reliable low resistance grounds were discussed. Advantages and drawbacks of using the following metals were given: Copper, copperclad steel, steel, zinc and zinc coated steel, magnesium, high silicon cast iron and corrosion resisting steels.

Members of the new task group T-4A-3, Methods and Materials for Grounding are: Irwin C. Dietze, Los Angeles Water and Power, chairman; and members Harry J. Keeling, consulting engineer; Alton F. Minor, American Telephone and Telegraph Co.; R. I. Perry, Commonwealth Edison Co.; V. B. Pike, Bell Telephone Laboratories; E. E. Westerhof, Consumers Power Co. and O. W. Zastrow, Rural Electrification Administration.

Liaison With Plastics Engineers Established

Task Group T-5D-7 on Engineering Design of Plastic Materials of Construction has established liaison with the Society of Plastics Engineers, Inc. Otto H. Fenner, Monsanto Chemical Co. has been appointed by NACE President L. L. Whiteneck to be official representative of the association in handling communications between the groups.

Task Group T-5D-7 was originated to work on a proposed type numbering system for the identification of plastic materials of construction.

Cooperation between the task group and the plastics society was suggested by P. W. Simmons, national president of the Society of Plastics Engineers, Inc. Mr. Fenner was named to the post in April.

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Biological Deterioration Unit Committees Formed

The Technical Practices Committee has approved formation of two unit committees of Group Committee T-9 on Marine Biological Deterioration. They are T-9A Biological and T-9B Preservations and Their Appraisal. The Technical Practices Committee met March 20 in San Francisco during the NACE 14th Annual Conference.

Charles E. Lane, marine laboratory University of Miami is chairman of T-9A. T. R. Sweeney, U. S. Naval Research Lab., is chairman of T-9B.

Scope of Sulfric—

(Continued From Page 65)

could be derived from concentrating on the newer materials of construction where present knowledge is limited. A questionnaire will be sent to members to obtain their opinions on which of several approaches will be undertaken. General problems of the sulfuric acid industry were discussed. W. A. Luce, The Duriron Co., Inc., chairman, represented the group.

It was decided that T-5A-2 Stress Corrosion Cracking in Alkaline Media, would be reactivated with C. P. Dillon, Union Carbide Chemicals Co. contacting former members to ascertain interest in the task group.

Acetic Acid Work Praised

The work of T-5A-3 Acetic Acid published in CORROSION was praised by W. H. Burton, General Chemical Div., Allied Chemical Corp., vice chairman of Committee T-5A and presiding officer at the meeting. The need continues for the group to continue as a clearinghouse for technical information, it was said. Resignation of Chairman Herbert Teeple was announced. Mr. Dillon is to appoint a committee to select a chairman.

A meeting of T-5A-4 Chlorine is scheduled to be held during the October North Central Region Meeting in Cincinnati. Tentative plans are to present the results of compiled answers at that time. The Bibliography of Corrosion by Chlorine (NACE Publication 56-2) will be reprinted by the Chlorine Institute. L. W. Gleekman, Wyandotte Chemicals Corp. gave the report on T-5A-4 activities.

Task Group T-5A-5 nitric acid has divided into three sub-task groups; Questionnaire, bibliography and nitric acid problems. The questionnaire has been approved by NACE, the bibliography was reported about half complete and no questions have been submitted for discussion. The group then discussed particular problems of interest to members. N. D. Groves, Carpenter Steel Co. gave the report as chairman.

HF Summary Presented

T-5A-6 HF Corrosion, was represented by T. L. Hoffman, Phillips Petroleum Co., Atomic Energy Div., chairman. A summary report, "Corrosion in HF Alkylation Units," by H. Bennett of Socony Mobil Oil Co. was discussed. When reviewed by the group it will be considered for publication. T. F. Degnan, E. I. duPont de Nemours & Co. has started to compile an HF bibliography and is planning to publish a paper on HF corrosion.

F. H. Meyer, National Lead Co. of Ohio, presented a report on uranium refining and recovery problems.

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Report on Stainless Steel Cracking Is Sent to Committee

A 15-page report, of which 14 pages are full of information exchanged among members of Unit Committee T-5E on Stress Corrosion Cracking of Austenitic Stainless Steels has been mailed to members of the committee. The report consists of minutes of the meeting held March 20 during the 14th Annual Conference in San Francisco.

Classification of corrosion conditions by Milt Holmberg, and a classification of steps taken to overcome cracking, materials and stress conditions by M. C. Bloom were completed and attached as part of the minutes. Revisions were to be made in classification according to types of equipment, locations of cracks and other considerations.

Work is continuing on the almost completed section on bibliography and research. The survey has been extended to Europe through ASTM A-10. Six replies have been received on the survey.

Copson in Informal Liaison

H. R. Copson agreed to act as informal liaison agent between NACE T-5E and the Pressure Vessel Research Committee of the American Welding Society. This group has a committee assigned to work on stress-corrosion cracking.

In considering points brought up by members on the subject of steps taken to overcome cracking, the various steps recommended were broadly classified into three categories: 1) change material. 2) change corrosion environment. 3) reduce the stress.

Materials Change Suggested

In the first category, change of material, several suggestions were made and examples given where attempts had been made to alleviate corrosion by using different materials.

In the second category, change of corrosion environment, suggestions were made to: Remove chlorides from the media, minimize chlorides by design change, coating to prevent chloride contact, reduce operating temperature and treat the water.

Concerning the third category, it was noted that while locked-in fabricating stresses often were recognized as a source of stress for cracking and many of the case histories contain recommendations to heat treat parts after fabrication or welding, that such recommendations come from alloy manufacturers rather than those fabricating or using the equipment. Problems of distortion and cleaning which accompany post-fabrication heat treatment are suggested as a reason a manufacturer is reluctant to recommend this method. In a few instances, design changes were suggested to reduce vibrational stress since there was apparently evidence of fatigue accompanying the stress corrosion failures.

Corrosion Conditions Classification

Another major part of the report concerned the Classification of Corrosion Conditions, a review of Parts 3 and 5 of the ASTM-NACE Survey on Stress Corrosion Cracking of Austenitic Stainless Steels. In summarizing, it was stated that data from the questionnaires indicate that under the proper conditions of stress and corrosive environments any of the austenitic stainless steels may stress-corrosion crack.

The data on gage and finish do not suggest that these are especially significant factors in themselves. Where information was provided, it appeared most items went into service with standard mill finishes. In one instance, an attempt apparently was made to mitigate cracking by using stress-relieved and highly polished tubes. This was not successful.

Hardness seems to be chiefly significant in indicating whether material has been severly cold worked and therefore contains internal stresses.

Locked-in Stress Paramount

The summary cited locked-in stress resulting from fabricating operations as being by far the most significant source of the stress producing cracking. Practically two-thirds of the cases fall into this category. However, often the operating stress was cyclic in character and the cracking might well have been predominantly corrosion fatigue rather than stress-corrosion cracking as conventionally defined. The writers were not aware of any reliable method of distinguishing between these two forms of cracking.

High Temperature Task Groups Are Reorganized

Reorganization of task groups to further the objectives of Unit Committees T-5B High Temperature Corrosion was a principal subject considered by the committee at is meeting in San Francisco, March 19.

Several possible groups suggested were:

Corrosion by Combustion Product Deposition—Would have a wide scope but would include boron-containing fuels specifically.

Metal Dusting—Encountered principally in hydrocarbon processing and which involves severe metal wastage.

Corrosion by Irradiated Nitrogen would study the likelihood of severe corrosion due to ionization of the gas, usually considered inert, under normal conditions, by neutron irradiation.

Standardization of Oxidation Data—The need was pointed out for systematized methods of obtaining and reporting oxidation data.

There are few usable data for temperatures above 1800 F.

"Safe" Sulfur Limits in Fuels—There seems to be no reliable quantiative data.

Corrosion by Molten Slag—Residual welding slag has led to extremely severe corrosion an increasing number of cases.

Protective Coatings for High Temperature Service—It was said that this important field should include both metallic and nonmetallic coatings and various coating systems and methods of application for high temperature service where corrosion is often very severe.

A report was given to the committee by E. R. Lind, Standard Oil Company of California on the problem of oil ash corrosion.

Next meeting of Unit Committee T-5B is scheduled at the North Central Region meeting in Cincinnati, Ohio, October 15-17, 1958.

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Kanawha Section Sponsors Northeast 1960 Sessions

Acceptance of an invitation to sponsor the 1960 Northeast Region Fall Meeting and installation of new officers highlight activities of the Kanawha Section.

The 1960 Northeast Region Meeting will be held at Huntington, W. Va. Invitation to the Kanawha Section to sponsor it was accepted, according to a report by Rod Schroeder, Standard Ultramarine and Color Co., outgoing section chairman. The following planning committee was elected to make arrangements for the 1960 meeting: Mr. Schroeder, general chairman; L. S. VanDelinder, Union Carbide Chemicals Co., program chairman; William Tufts, Ashland Oil & Refining Co., arrangements chairman.

New section officers for 1958-'59 were installed at the May 1 dinner meeting held at Charleston, W. Va. New officers

(Continued on Page 70)

Canadians Prominent On Northeast Program

Canadian speakers will have a prominent part in the Northeast NACE Regional Conference, October 6-8 in Boston. Five speakers from Canada, each considered an authority on his subject, have accepted invitations to talk and possibly to present papers. Negotiations are continuing to secure other Canadian speakers. In addition approximately 30 persons from the United States will make addresses at the conference.

Canadian speakers already scheduled are: J. A. H. Carson, Pacific Naval Lab., Esquimalt, B. C.; W. L. M. Phillips and J. R. Wellington, Consolidated Mining & Smelting Company of Canada, Ltd.; T. H. Rogers, Naval Research, Dockyard Lab., Halifax, N. S., and K. N. Barnard, Naval Research Establishment, Halifax.

The well-rounded technical program and out of the ordinary entertainment and banquet are expected to attract many.

Pittsburgh Section Elects S. H. Kalin Chairman

New officers for the Pittsburgh Section were elected at an April 3 meeting. S. H. Kalin, U. S. Steel Research Laboratories is the new chairman; R. W. Maier, Gulf Oil Corp., vice-chairman; Grant Snair, Allegheny Ludlum Steel Corp., secretary and John Vrable, New York State Natural Gas Co., treasurer.

Progress Reported On Boston October Technical Program

The task of finding men experienced in the complex planning of a regional conference is easier than usual for the NACE Northeast Region meeting October 6-8 in Boston. Many men on the various committees have previous experience in similar regional and national activities.

The conference committee is headed by Harvey Miller, New England Hard Facing Co., Inc., experienced in conference work. Mr. Miller named as committee chairmen: Manson Glover, Glover Coating Co., Inc., finance and budget; Daniel Cushing, Consulting Metallurgist, technical practices; Murray Jacobson, Watertown Arsenal Labs., technical program and W. E. Langlois, Westinghouse Electric Corp., publicity and printing.

Boris Tytell, Navy Bureau of Ships is in charge of field trips; Herbert Howe, Worcester Industrial Rubber & Supply Co., entertainment; John Hendrick, American Durafilm Co., Inc., banquet and ladies' entertainment; Stanley Warshaw, Technical Coatings, Inc., housing and hotel accommodations and Benjamin Barnwall, Technical Coatings, Inc., registration.

Simultaneous sessions will be employed in the technical program to allow those interested in a subject to attend all meetings on that subject. Great interest in salt water corrosion is recognized by an extensive symposium on marine corrosion. Other symposia subjects are: Cathodic protection, theory and principles of corrosion, power industry, protective coatings and general corrosion problems. Many speakers, some of them internationally known, are committed to deliver talks and present papers.

Because of its reputation as a vacation spot, and New England's scenic beauty in the Fall, conference officials believe many of those attending will make the trip a combination of business and pleasure. Boston is easily accessible by all forms of transportation. One special treat not to be found in any other region of the United States is a "real old-fashioned New England clam bake" which will be an entertainment feature. Following the clam bake, there will be a visit to the world famous Clapp Marine Laboratories. To make the conference a social as well as a technical success, the entertainment committee is working intensively to arrange an enjoyable program and a good banquet.

An entire wing of the Hotel Somerset has been set aside for the conference. Many out-of-town guests will be able to register in the Somerset. Other first class hotels are close by.

Demonstrating the growth of scien-

(Continued on Page 70)

35 of 40 Papers Committed for Boston Northeast Region Meeting October 6-8

Committments for 35 of the 40 scheduled papers to be given at the October 6-8 Northeast Regional Meeting in Boston have been announced. These papers will be presented in seven symposia, three of which will consist of two sessions each. Fields trips are planned for the Boston Naval Shipyard and to the Clapp Marine Laboratories. Concurrent sessions will be held.

Four papers scheduled for the Marine Corrosion Symposium will be by Canadian scientists.

Meetings of technical committees will be scheduled insofar as possible not to conflict with symposia.

A social program is being arranged.

The schedule of symposia and papers committed is:

Monday, October 6

Theory and Principles

Principles and Use of Polarization Instruments, H. H. Uhlig, Massachusetts Institute of Technology.

Electrochemical Methods for Measurement of Corrosion Rates, M. Stern.

Studies on Oxygen Reduction Polarization Reactions, A. DeBethune.

Marine Corrosion

Marine Corrosion Testing, T. P. May, International Nickel Co., Inc.

Subject to be announced, K. N. Barnard, Naval Research Establishment, Halifax, N. S.

Platinum Anodes for Cathodic Protection of Active Ships, H. S. Preiser and B. H. Tytell, Navy Bureau of Ships.

Aluminum Anode Applications on Offshore Structures and Marine Pipelines, R. L. Horst, Aluminum Co. of America.

Combined sessions: H. R. Copson, International Nickel Co., Inc., is expected to talk on stress corrosion cracking.

Cathodic Protection

Designing Corrosion Control for Power Plants Using the Cathodic Protection Principle, L. P. Sudrabin, Electro Rust-Proofing Corp.

Use of Zinc Anodes for Cathodic Protection, J. L. Kimberley, American Zinc Institute.

Current and Potential Relations for the Cathodic Protection of Steel in a High Resistivity Soil, W. J. Schwerdtfeger, National Bureau of Standards.

Electrode Reactions Associated with Cathodic Protection, E. E. Nelson, Socony Mobil Oil Co.

ERROR IN MAILING MADE TO SOME MEMBERS

In an April 7 mailing to members of NACE concerning the Northeast Region Meeting in Boston, copies of the program for Tuesday afternoon and Wednesday were inadvertently omitted from some envelopes. The complete program as announced in that mailing is reproduced here for the information of those who received the erroneous mailings.

Tuesday, October 7

Cathodic Protection

Application of High Silicon Iron Anodes, W. A. Luce, The Duriron Co.

Some Observations on Zinc Anodes for Cathodic Protection in Sea Water, M. C. Bloom, Naval Research Laboratory.

Graphite Anodes for Cathodic Protection, J. J. Miller, National Carbon Co.

Galvanic Anodes as a Supplement to Coatings in Brewery Pasteurizers, C. W. Ambler, American Zinc, Lead and Smelting Co.

Subject to be announced, B. Douglas, Dow Chemical Co.

Marine Corrosion

Uses and Abuses of Aluminum in Wooden-Hulled Minesweepers, T. H. Rogers, Naval Research-Dockyard Lab., Halifax, N. S.

Design of Cathodic Protection Systems for Ships' Hulls, J. A. H. Carson, Pacific Naval Laboratory, Esquimalt, B. C.

A Laboratory Evaluation of Zinc Anodes, W. L. M. Phillips, J. R. Wellington, Consolidated Mining and Smelting Co. of Canada, Ltd. and J. A. H. Carson, Pacific Naval Laboratory, Esquimalt, B. C.

Two more papers are scheduled to be held.

Protection Coatings

Methods of Studying the Interactions Between Organic Coatings and Metals, M. Kronstein, New York University.

Subject to be announced, L. R. Whiting, Bakelite Co.

Evaluation of Marine Service Coatings When Exposed to Tropical Environments, A. L. Alexander, Naval Research Laboratory.

Glass Reinforced Plastic Coatings, W. R. Graner, Bureau of Ships.

Teflon Coatings, G. Mell, E. I. duPont de Nemours & Co., Inc.

Coal Tar Coatings and Surface Preparation, W. F. Fair, Jr., Koppers Co.

Chemically Modified Coal Tar Coatings, F. Charlton, Koppers Co.

Sprayed Metal Coatings, J. C. Ritter, Boston Naval Shipyard.

Another paper is scheduled also.

Wednesday, October 8

Power Industries

Liquid Metals for Use in a Nuclear Reactor, W. D. Manly. Oak Ridge National Laboratory.

Subject to be announced, E. G. Brush, General Electric Co.

Two more papers are scheduled.

General Corrosion

Visual Demonstration of Corrosion Processes, G. C. Cox, Consultant.

Subject to be announced, C. F. Schrieber, Dow Chemical Co.

Subject to be announced, E. A. Anderson, New Jersey Zinc Co.

Some Characterstics of Sodium Silicate as a Corrosion Inhibitor, S. Matsuda and H. H. Uhlig, Massachusetts Institute of Technology.

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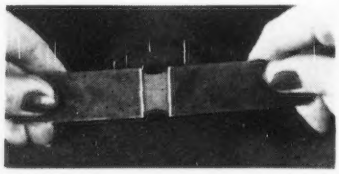

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Kanawha Section—

(Continued From Page 69)

are: George C. Cox, consultant, chairman; Conrad L. Wiegers, Allied Services, Inc., vice chairman; Kenneth R. Gosnell, development department, Union Carbide Chemicals Co., secretary; W. J. Foster, E. I. duPont de Nemours & Co., program chairman; Russell Davisson, development department, Union Carbide Chemicals Co., publicity chairman; Jack G. Brown, United Fuel Gas Co., arrangements chairman; George F. Orr, Hill Hubbell Co., Division of General Paint Co., membership chairman; Arthur E. Bliss, L. Sonneborn Sons, Inc., hospitality chairman; L. G. Moore, Tennessee Gas Transmission Co., by-laws chairman; Paul Dillon, Union Carbide Chemicals Co., corporate membership chairman; William R. Lambert, production department, United Fuel Gas Co., Engineers' Week; W. H. Williams, McJunkin Corp., and J. L. Barker, Jr., Union Carbide Chemicals Co., Kanawha Valley Technical Section.

Scheduled for the May 22 meeting at Marietta, Ohio was a talk and demonstration by Lowell Hawthorne, Revere Copper and Brass, Inc., of the Revere welding gun.

Experienced Group—

(Continued From Page 69)

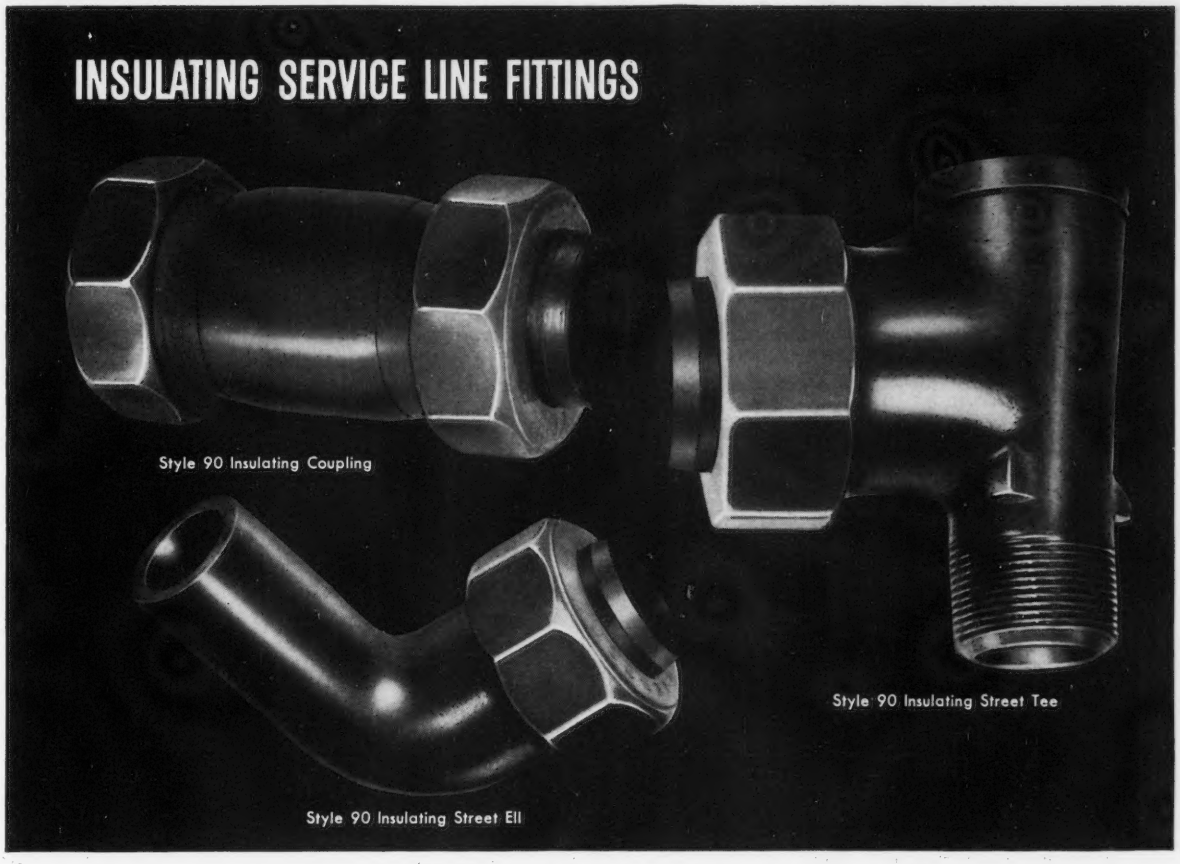
tific interest in corrosion, colleges and universities throughout New England have displayed interest in the conference. Several already have requested that their students be allowed to participate and special arrangements are being set up whereby large numbers of students will have an opportunity to attend the conference.

•

Corrosion subscribers live in over 40 foreign countries.

•

During 1957 over 140 discussions to technical material published in CORROSION appeared.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Gas utility men agree that the service line, being nearest to the consumer, deserves the best protection from these two major causes of corrosion: stray d-c currents and dissimilar metals.

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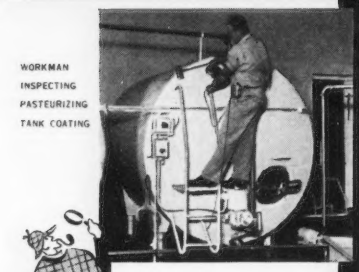

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San Joaquin Tour Is Scheduled for September 24-25

The Guided Field Corrosion Tour to be conducted by the San Joaquin Valley Section will be held Sept. 24-25, 1958. Purpose of the tour is to study and examine corrosion projects pertaining to the petroleum, refining, public utilities and agricultural industries.

Projects to be exhibited will be selected so that case histories and data can be followed on future tours. Wash tanks, boilers, coated lines, sucker rods and other pieces of equipment will be exposed for visual examination. A case history will be available for each exhibit.

Headquarters will be Bakersfield, Cal., and the tour will cover the Southern San Joaquin Valley area. More information may be obtained by writing Jerry Mitchell, Nocor Chemical Co., 3133 Monterey St., Bakersfield, or Jack Penner, Magna Products, 305 East Brundage Lane, Bakersfield, California. Fee for the course has not been set.

Members of the various committees are: Jerry Mitchell, Nocor Chemical Co., general tour chairman; Jim Wilt, Honolulu Oil Corp., is exhibits chairman, with committee members C. J. Smith, Western Gulf Oil Corp. and A. J. Nierman, Standard Oil Company of California; Jack Penner, Magna Products, registration; E. A. LeDuc, Dearborn Chemical Co., transportation and equipment; C. B. Barton, Tret-o-lite Corp., chairman of tour guide, with E. A. LeDuc and J. Penner as members.

Herb Rose, Superior Oil Co., is publicity chairman with Robert Flammang, Richfield Oil Corp. as member; J. Mitchell, hospitality; and Richard Stark, Pacific Gas & Electric Co. is secretary. Chairman of the section is R. L. Davis, Superior Oil Co.

Cathodic Protection Is Topic at Chicago Section

At the April 15 Chicago Section meeting members and guests heard Porter Hart, The Dow Chemical Co., Freeport, Texas speak on "Design and Application of Cathodic Protection in Industrial Plants." Mr. Hart described the use of magnesium to prevent corrosion of underground structures.

Copper ground beds led to many early failures so they are no longer used, he said. Cathodic protection of sea water screens, pipe lines, vessels and skimmer areas also was explained. Numerous questions after his talk indicated good interest in the subject. Mr. Hart has been active in corrosion control work for 28 years.

Shreveport Section to Hold Annual Barbecue June 6

The annual "Stag Barbecue" of Shreveport Section will be held at the Texas Company Club House on Cross Lake, June 6, L. B. Irish, Irish Engineering Service, section chairman announced. The event is scheduled from 4:30 until midnight with dinner at 6:30.

●

CORROSION's index appears in December.

CORROSION'S ABSTRACTS MORE THAN ADEQUATE

Abstracts published in CORROSION's Abstract Section have been found more than adequate to justify discontinuance by one of the nation's largest oil companies of its abstracting of corrosion articles. The company will continue to abstract only the literature on oil-soluble corrosion inhibitors.

In the notice that the abstracting has been discontinued it was reported: "All corrosion abstracts that have been published in this bulletin—and more—are available currently in the Corrosion Abstracts published in the journal CORROSION by the National Association of Corrosion Engineers. These abstracts are also available from the NACE on edge-notched cards."

New Orleans Exhibit Sales Are Brisk

Exibit space sales are proceeding at a brisk space in the October 21-23 show to held at Hotel Roosevelt in New Orleans, concurrently with the South Central Region's 1958 Conference. More than half the booth space initially laid out has been sold, according to R. W. Huff, Jr., exhibition manager. Mr. Huff said there is still a good selection of spaces for firms who have not yet sent in their reservation.

The exhibition area in the hotel is located between the elevators and stairs and the principal rooms in which technical symposia and meetings will be held. This, and the careful arrangement of booth areas, is designed to assure good traffic through the exhibit.

This will be the third exhibition held by NACE's South Central Region. The attractions of a five-day technical program oriented to the region's principal industrial interests and the undeniable attractions of New Orleans for extracurricular activities, is expected to bring good attendance.

As in other years attendance by NACE members and others from NACE's Southeast Region is expected to be good. It is confidently expected that the number attending from outside the region may set a record.

Early scheduling of technical committee meetings, especially in the oil, petrochemical, gas and paint fields, indicates a well-rounded program. The whole of the first days of the meeting, Monday, Tuesday and Wednesday, October 20, 21 and 22 will be devoted to technical committees. Technical symposia will be held on Thursday and Friday, October 23 and 24.

The usual meetings of South Central Region's standing committees will be held.

Southwestern Ohio Section

A "Mr. and Mrs. Outing" was planned for the Southwestern Ohio Section meeting at Clifty Falls State Park, Madison, Indiana on May 23. Games, horseback riding and tennis were on the recreation schedule.

Plans were for members and guests to eat at State Park Inn. A movie on corrosion was scheduled to be shown.

Progress Reported on Los Angeles Fall Meeting

The technical program and other important elements of the Western Region Meeting to be held in Los Angeles' Statler Hotel, November 17-19 are progresing satisfactorily, according to chairmen of the various committees who reported to the conference committee.

Technical Program Committee Chairman J. I. Richardson, Amercoat Corp., said symposia chairmen were trying to have commitments on most of the technical papers by May 15.

A "workshop" type short course on protection of underground structures and pipe lines will be held November 20-21 beginning the day after the Fall region meeting. It will include practical applications of surface preparation, paint and plastic coatings, pipeline coatings and wrappings and cathodic protection. It probably will be held on the grounds of the Standard Oil Company of California, El Segundo, Cal. J. R. Brown, Kobe, Inc., education chairman reported on progress of the short course.

H. E. Tillman, Koppers Co., Inc., facilities chairman said that all preliminary arrangements have been completed with the Statler Hotel.

South Central Technical Papers Deadline Set

Symposia chairmen working to complete their complement of technical papers for the South Central Regional Conference in New Orleans, La., October 19-24 were given deadlines for completion of phases of the program.

Deadline for selection of speakers and authors for symposia was April 28. Deadline for completion of symposia, speakers, authors and topics, was May 22. Publicity for JULY CORROSION has a deadline of June 5. Deadline for receipt of abstracts of papers to be presented is June 15.

Authors' information forms and copies of the NACE policy on publication of technical papers also have been sent to symposia chairmen.

Symposia and chairmen for the meeting are: Oil and Gas Production, Jack Battle, Humble Oil & Refining Co., chairman; Cliff Koger, Cities Service Oil Co., vice-chairman. Marine Corrosion, Otto L. Grosz, The California Co., chairman; Norman Dunne, Shell Oil Co., vice-chairman. Pipe Line, Marion Frank, Tennessee Gas Transmission Co., chairman; no vice-chairman had been named. Refining and Process Industries, W. L. Vorhies, Freeport Sulphur Co., chairman; R. M. Eells, Esso Standard Oil Co., vice-chairman. Utilities, J. L. Love, Water Dept., City of Lafayette, chairman; no vice chairman has been named.

Thin Platinum Films Sturdy

Platinum films on the order of 0.000005-inch thick deposited on the surface of titanium anodes showed no deterioration after carrying anodic currents with densities as high as 100 ampere sq. ft. in sea water for 250 hours. This is reported in "Platinum-Faced Titanium for Electrochemical Anodes, by J. B. Cotton in "Platinum Metals Review," Vol. 2, No. 2, Pages 45-47.

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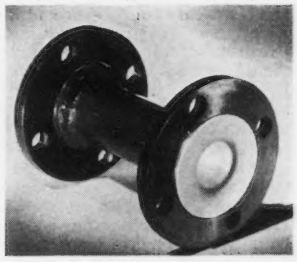

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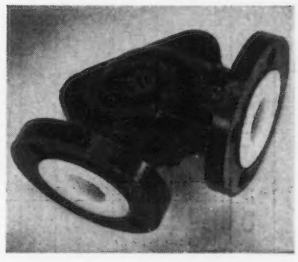

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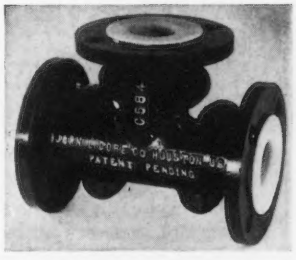

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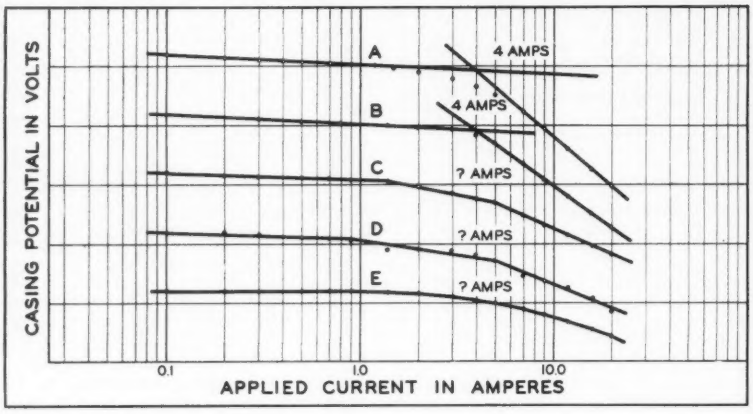
Teflon Is Topic at Dallas May Session

North Texas Section scheduled a technical talk on "Future Materials and Equipment Applications for Corrosion Prevention" for the May 5 meeting at the Torch Restaurant, Dallas. L. A. Ferris, E. I. duPont de Nemours, was the speaker. Mr. Ferris planned to present a paper in the form of a clinic chiefly on the subject of Teflon.

The section has submitted its quarterly report and in addition has made inquiries on procedure to be used in setting up a scholarship by the section. Donald F. Taylor, section secretary treasurer did not say plans are now being considered to establish a section scholarship.

The section participated in an Annual Student Engineers Banquet sponsored by the Dallas Engineers and Technical Societies. Glynn Beesley, Dallas Power and Light Co., a member of the presiding group represented North Texas Section. Of the 297 students, eight were sponsored by the section and attended the banquet held in the Baker Hotel Crystal Ballroom, April 24. Each student was sponsored by an engineer who paid for both tickets. Ed Muehlhause, Lone Star Gas Co., was section ticket chairman for the event. Several awards and scholarships are presented as part of the annual affair.



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The trouble is, however, that unless they are made correctly, such curves are useless. Curves A and B above, made by CSI, allow a correct appraisal of the current required. Curves C, D and E, made by an inexperienced engineer, defy interpretation. They are the result of either faulty instrumentation or operational techniques.

CSI engineers are experts in this field. They have obtained curves like A and B on hundreds of wells. They design and install cathodic protection systems for pipelines, oil and gas wells, etc.—using either rectifiers or Dow magnesium anodes as the current source. Protection for oil and gas wells has averaged about $300 per well—for a system designed for ten years of protection, installed on a turnkey basis.

For more information, service or quality supplies, call or write today. Estimates of quotations without obligation. Ask for free copies of the latest CSI reports on "Hot Spot Protection" and "The Truth About The Current Efficiency of Galvomag Anodes."

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CENTRAL OFFICE STAFF

Bonner

Graham

Ann Graham and Bessie Bonner of NACE Central Office accounting department are responsible for the association's financial records.

Miss Graham is head of the department. She has been with NACE since March, 1947 when NACE had about one-fourth the members it has now. Miss Graham also attends to the many details of social security, hospital insurance and the newly installed retirement pension plan for employes. She is a graduate of the University of Texas with a BBA degree, where she specialized in statistics and accounting.

Miss Bonner has been with NACE since October, 1956. She has been keeping records on association members, recording changes of address, payment of dues, invoicing members for dues, and keeping other information. She also acted as purchasing agent.

Under a recent realignment of duties for Central Office personnel, Miss Bonner will be given more extensive accounting duties to assist Miss Graham in the growing accounting load of the association. She is a native of Mansfield, Ohio, but has lived in Texas since 1955.

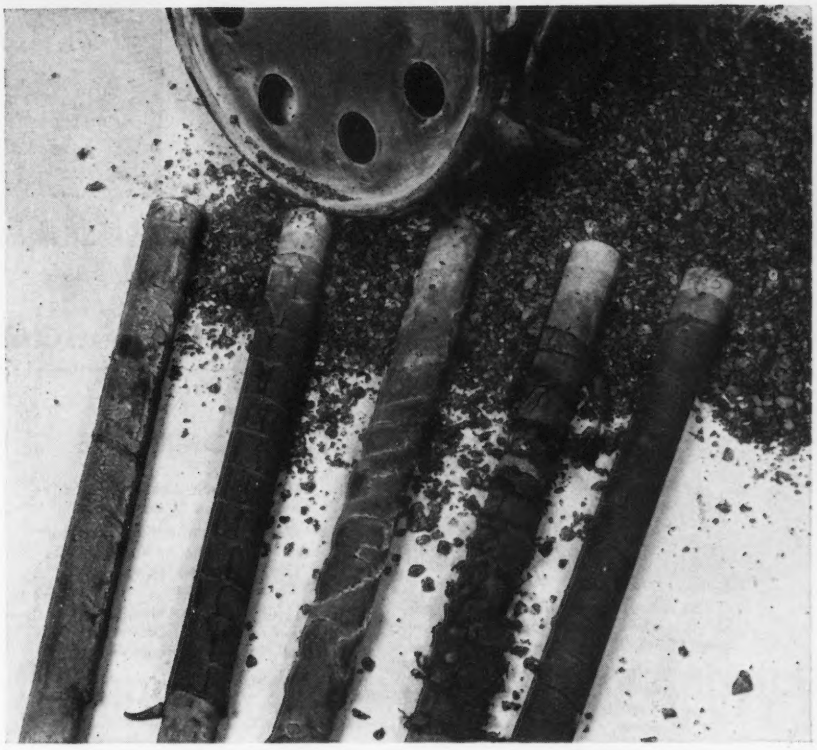
Birmingham Section Discusses Cooperation

For its June quarterly meeting, Birmingham Section scheduled Stewart H. Gates, Southern Bell Telephone and Telegraph Co., transmission and protection engineer for Kentucky as the technical speaker. The subject selected by Mr. Gates was "The Committee Approach to Corrosion Problems." He has had extensive corrosion experience, and is chairman of the Louisville Electrolysis Committee.

A joint meeting with the Birmingham Electrolysis Technical Committee was planned for the Molton Hotel, June 6 at 7 pm. George Speake is program chairman for Birmingham Section.

Air Pollution Course Is Offered by Pittsburgh U.

University of Pittsburgh's Graduate School of Public Health is offering a nine-month courses with emphasis on methods of appraisal and engineering control of air pollution. The course covers principles, measurements and practice. Inquiries should be directed to M. A. Shapiro, Associate Professor of Sanitary Engineering, Graduate School of Public Health, University of Pittsburgh, Pittsburgh 13, Pa.



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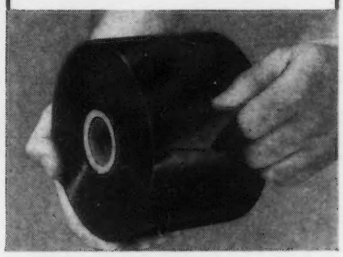

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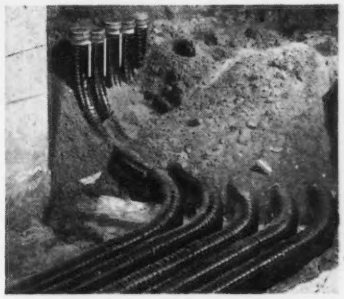
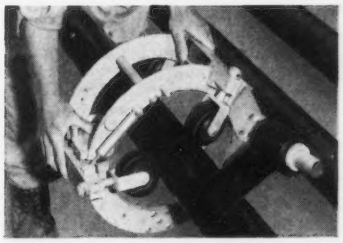
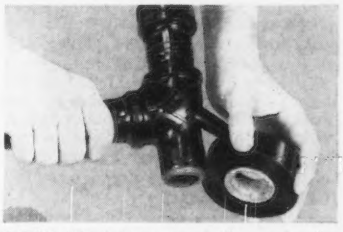


ACTUAL field use shows why abrasion-resistance of "SCOTCHRAP" is important: backfill is coarse, rough—could easily puncture or tear less tough coatings.



SAVE TIME on total system coverage. With wide-width "SCOTCHRAP" and "Betzel" Tapester, one man covers 200 feet of 4″ pipe in less than 30 minutes.



INSULATE joints, tees, elbows in the field. Supercomformable "SCOTCHRAP" does it quickly. For complete information on "SCOTCHRAP", or to arrange demonstration, write: 3M Co., 900 Bush Ave., St. Paul 6, Minn., Dept. BQ-58.

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Nominations for National Officers Are Made

Godard, Best and Stegner Named for Top NACE Posts

Nominations of candidates for election to the highest offices in the National Association of Corrosion Engineers have been received from the nominating committee. Officers elected will serve for the 1959-60 term. H. P. Godard is nominated for president; George E. Best for vice president and A. L. Stegner for treasurer.

Nominated for terms on the board of directors were: Jack P. Barrett and Edward L. Simons both to represent NACE active members and Guy F. Williams, to represent corporate members. The official report of the nominating committee is printed in this issue of CORROSION.

Nominations made by the committee can be supplemented by nominations from active members of NACE in accordance with Paragraph Three of Section 3, Article VIII of the NACE Articles of Organization which states:

"Not later than a date to be fixed as provided in Section 5 of this Article, (Article VIII). The Secretary shall inform all members of the Association, by publication or otherwise, of the list of nominees reported to him by the Nominating Committee; and at any time prior to a later date, to be fixed as provided in Section 5 of this Article, additional nominations may be made by petition forwarded to the Secretary and signed by at least twenty-five (25) Active Members. Any such nominees for the office of President, Vice-President or Treasurer shall qualify as provided in the first paragraph of this section."

As indicated by the schedule published in this issue of CORROSION, active members have until July 11 to submit the names of additional nominees by petition. Voting will be by letter ballot in August, with October 24 the deadline for votes to be in Central Office. Tellers will have until December 13 to prepare their report of the ballot count.

BIOGRAPHIES

HUGH P. GODARD, Aluminium Laboratories, Ltd. is now vice-president of NACE. He has been active in the association in other capacities, serving on the board of directors and has worked with technical committees. He is a member of T-3B on Corrosion Products, T-6G on Surface Preparation for Organic Coatings and of the technical practices managing committee. He is ex-officio member of the Technical Practices Committee. He has served as a member of the corrosion abstract subcommittee of the Publication Committee

(Continued on Page 81)

OFFICIAL:

REPORT of the NOMINATING COMMITTEE

A meeting of the Nominating Committee to select candidates for President, Vice-President, Treasurer and three Directorships was held at the Annual Conference at 11:00 A. M. on Friday, March 21st.

The following nominees were selected for the above offices for terms beginning March 20, 1959:

For President:
Hugh P. Godard, Aluminium Laboratories, Ltd., Kingston, Ontario.

For Vice-President:
George E. Best, Solvay Process Div., Allied Chemical & Dye Corp., Baltimore, Maryland.

For Treasurer:
A. L. Stegner, Tennessee Gas Transmission Co., Houston, Texas.

For Director representing active members (two to be elected):
Jack P. Barrett, Pan American Petroleum Corp., Tulsa, Oklahoma
Edward L. Simons, General Electric Research Laboratory, Schenectady, New York.

For Director representing Corporate membership (one to be elected):
Guy F. Williams, Dowell Inc., Tulsa, Oklahoma.

Schedule of Dates For Nomination and Election of National Officers and Directors for Terms Beginning March 20, 1959

Activity	Date to be completed
Formation of Nominating Committee (completed)	March 21, 1958
Nomination of Candidates and report to the Secretary (completed)	May 1, 1958
Publication of Nominating Committee Report	June 1958 Issue of CORROSION
30 to 35 days for members to prepare and file nominations by petition	July 11, 1958
Preparation and mailing of letter ballots to NACE members	August 22, 1958
Period allowed for members to return letter ballots	October 24, 1958
Period allowed to count ballots and prepare report by tellers	December 13,1958
General Business Meeting	March 18, 1959

List of Members Eligible for Nomination to the Office of President, Vice President or Treasurer of the National Association of Corrosion Engineers for the Term Beginning March 20, 1959.

H. H. Anderson
N. E. Berry
G. E. Best
H. L. Bilhartz
R. A. Brannon
E. G. Brink
H. R. Brough
J. Pat Casey, Jr.
W. R. Cavanagh
Stephen P. Cobb
F. E. Costanzo
Stephen D. Day
Irwin C. Dietze
L. B. Donovan
M. G. Fontana
H. P. Godard*
E. C. Greco
C. G. Gribble
H. F. Haase
Norman Hackerman
H. L. Hamilton
Jack W. Harris
Tom L. Holcombe
Derk Holsteyn
A. N. Horne
R. B. Hoxeng
L. A. Hugo
H. A. Humble
V. N. Jenkins
T. F. P. Kelly
V. V. Kendall
W. J. Kretschmer
R. E. Kuster
F. L LaQue
C. P. Larrabee
R. J. Law
R. H. Lynch
J. T. MacKenzie
E. D. McCauley
R. McFarland, Jr.
George B. McComb
F. J. McElhatton
V. V. Malcom
T. P. May
R. B. Mears
C. G. Munger
A. R. Murdison
O. E. Murrey
W. R. Myers
E. P. Noppel
G. R. Olson
Ivy M. Parker
R. R. Pierce
Robert Pope
E. C. Range
W. F. Rogers
L. F. Scherer
H. W. Schmidt
L. R. Sheppard
A. D. Simpson, Jr.
P. H. Smith
D. E. Stearns
A. L. Stegner
E. H. Tandy
R. S. Treseder
H. M. Trueblood
H. C. Van Nouhuys
E. D. Verink, Jr.
Aaron Wachter
H. E. Waldrip
L. C. Wasson
John B. West

* Eligible for nomination for President only.

Any Active Member in good standing is eligible for nomination as a director to represent the Active Membership of the Association and any Representative of a Corporate Member in good standing is eligible for nomination as director to represent the Corporate Members of the Association, except the following who are not eligible for nomination as an elected director for the term beginning March 20, 1959—because of the time limitation in Section 5, Article IV of the Articles of Organization.

List of Members Not Eligible for Nomination as Director for Term Beginning March 20, 1959.

G. E. Best
H. L. Bilhartz
R. A. Brannon
E. G. Brink
H. R. Brough
F. E. Costanzo
W. F. Fair, Jr.
H. P. Godard
C. G. Gribble
H. F. Haase
H. L. Hamilton
J. W. Harris
R. E. Kuster
T. P. May
R. McFarland, Jr.
C. G. Munger
A. R. Murdison
R. R. Pierce
A. L. Stegner
W. H. Stewart
E. P. Tait
E. H. Tandy
R. S. Treseder
H. E. Waldrip
L. C. Wasson
J. B. West
L. L. Whiteneck
F. L. Whitney, Jr.

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Unique formula cures quickly into a tough, tightly bonded, abrasion resistant shield against corrosive chemicals and fumes.

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Arocoat has been used profitably to cut traditional corrosion losses in paper mills . . . to add new life to condensate tanks and vessels, hopper cars, casing and conveyors . . . to provide internal or external protection for acid, alkali, sour crude and brine storage tanks . . . to reduce maintenance costs on cooling tower equipment.

Economically applied by spray or brush, it has also been used to provide superior protection for marine equipment and submerged, buried and exposed gas and petroleum transmission lines.

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Coburn

Collings

Henneberry

Janota

McFarland

Risetter

Rue

Schultz

Sheldahl

About Your CONFERENCE OFFICIALS

R. B. JANOTA, Swift & Company Research Laboratories, general conference chairman, is research chemist for the firm where he heads the paints and construction materials division and industrial bonding compound division. He gained conference experience as general arrangements chairman of the 1957 North Central Regional meeting which was also held at the Sherman Hotel. He joined NACE in 1949 and at present is active in NACE technical organizations, being a member of Unit Committees T-3E on Railroads, T-5D on Plastic Materials of Construction and Task Group T-3E-1 on Corrosion of Railroad Tank Cars. Besides his work in NACE, he is a member of the Federation of Paint, Varnish Production Clubs and of various ASTM sub-committees.

R. McFARLAND, Hills-McCanna Co., technical program chairman, has been associated actively with the design and application of pumps, valves and allied equipment of both metallic and non-metallic materials. He is secretary and technical director of Hills-McCanna Co. He is active in four NACE technical organizations working on protective coatings, being chairman of one, T-6A-1 on Rubber Linings, and also is a member of T-5D on Plastic Materials of Construction. He is a graduate of Armour Institute of Technology's school of chemical engineering; he did graduate work in organic chemistry at University of Chicago. He is a member of AIChE, ACS, ASM, Tappi and MSS.

SEYMOUR K. COBURN, research chemical engineer, engineering division, Association of American Railroads, is technical program co-chairman. He is active in NACE work, being chairman of Unit Committee T-3A on Corrosion Inhibitors; chairman of T-3C on Annual Losses Due to Corrosion; a member of T-3, General; T-3E on Railroads; and of T-3E-1 on Corrosion of Railroad Tank Cars. He is editor of the Railroad Corrosion News Letter and has had articles published in the Journal of the American Chemical Society; and in Official Digest, Proceedings of American Railway Engineering Association. He also is a member of ACS, ASM and Sigma Xi. He received a BS in chemistry from the University of Chicago and an MS in chemistry from Illinois Institute of Technology.

WAYNE H. SCHULTZ, Dearborn Chemical Co., exhibition chairman, joined NACE more than 12 years ago. He presently is engaged in coordinating sales, production and research for the pipe line division of Dearborn Chemical. He formerly was in the firm's coating and wrapping sales department. He has more than 25 years in corrosion control work, having worked with a major mill coating and wrapping applicator and with a pipe line contractor. He was one of the organizers and first chairman of the Rocky Mountain Section, NACE and presently is active in Chicago Section.

L. V. COLLINGS, Sinclair Research Labs., is publicity chairman for the conference. He was vice-chairman of technical committee meetings held at the North Central Region Meeting, Chicago, October 1-4, 1957. He is in the corrosion division of Sinclair Research Labs.

D. B. SHELDAHL, Sinclair Research Labs. is local arrangements chairman. He has been active in NACE Chicago Section, serving as chairman of arrangements, on the program and by-laws committees. He has been with Sinclair since graduation from Iowa State College in 1936 with a BS in chemical technology. He has worked in various capacities with Sinclair and has been a member of the firm's corrosion division since it was organized in 1948, specializing in corrosion inhibitor development and testing.

P. E. HENNEBERRY, Amercoat Corp., entertainment chairman also gained experience from the 1957 North Central Region Meeting. He was chairman of the local arrangements committee and co-chairman of the general arrangements committee where he acted as liaison man on exhibits. He joined Amercoat Corp. in 1954. Prior to that he was associated with Phillips Chemical Co. He received a PhB from Loyola University in philosophy and

(Continued on Page 84)

Reduced Conflicts Principal Aim of Planning Group

If concerted efforts of officials of the NACE 15th Annual Conference and 1959 Corrosion Show are successful, corrosion engineers will find it easier to take part in important meetings they want to attend.

More than ordinary efforts are being exerted to schedule meetings so there will be a minimum of conflicts.

Before the 14th NACE Conference in San Francisco was over, officials of the coming 15th Annual Conference and 1959 Corrosion Show to be held in Chicago, March 16-20 were hard at work on the many complex details necessary to stage a successful conference.

In overall charge of the conference is Rudolph B. Janota, Swift & Company Research Laboratories, general conference chairman. Others in vital positions are Rolland McFarland, Jr., Hills-McCanna Co., technical program chairman and S. K. Coburn, Association of American Railroads, technical program co-chairman. W. H. Schultz, Dearborn Chemical Co., is the exhibition chairman. All exhibits and technical meetings will be held in the Sherman Hotel.

Other key committees and their chairmen are: L. V. Collings, Sinclair Research Labs., publicity; D. B. Sheldahl, Sinclair Research Labs, local arrangements; P. E. Henneberry, Amercoat Corp., entertainment; J. J. Irwin, Revere Chemical Co., Inc., registration chairman and Richard Rue, Insulmastic Corp., program coordinating. L. O. Rissetter is cooperating in planning the ladies program.

The convenience of having exhibition halls and technical meeting rooms concentrated in the Sherman Hotel; with an experienced conference staff and with Chicago being centrally located and easily accessible by all forms of transportation, make officials optimistic that attendance will be high and the show a success.

Early Deadline Set On Conference Papers

Authors of technical papers to be presented at the 15th Annual NACE Conference and 1959 Corrosion Show will have to meet a deadline of January 9 for submitting their manuscripts if they are to be included on the technical program.

Conference officials, meeting with symposia chairmen, said the deadline will be strictly adhered to and that no papers received after January 9 will be presented at the 15th Annual Conference.

The decision was necessary to provide time for processing manuscripts, preparing printed programs and making other scheduling arrangements. The 15th Annual NACE Conference and 1959 Corrosion Show will be held next March 16-20 in Chicago.

•

The exhibition scheduled to be held at New Orleans October 21-23 during the South Central Region's Conference at The Roosevelt Hotel will be the third held by the region.

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1959 Corrosion Show Contracts Are Sent Out

EXHIBIT AREA
•
FLOOR PLAN

So Everyone Can See the Show
There will be a
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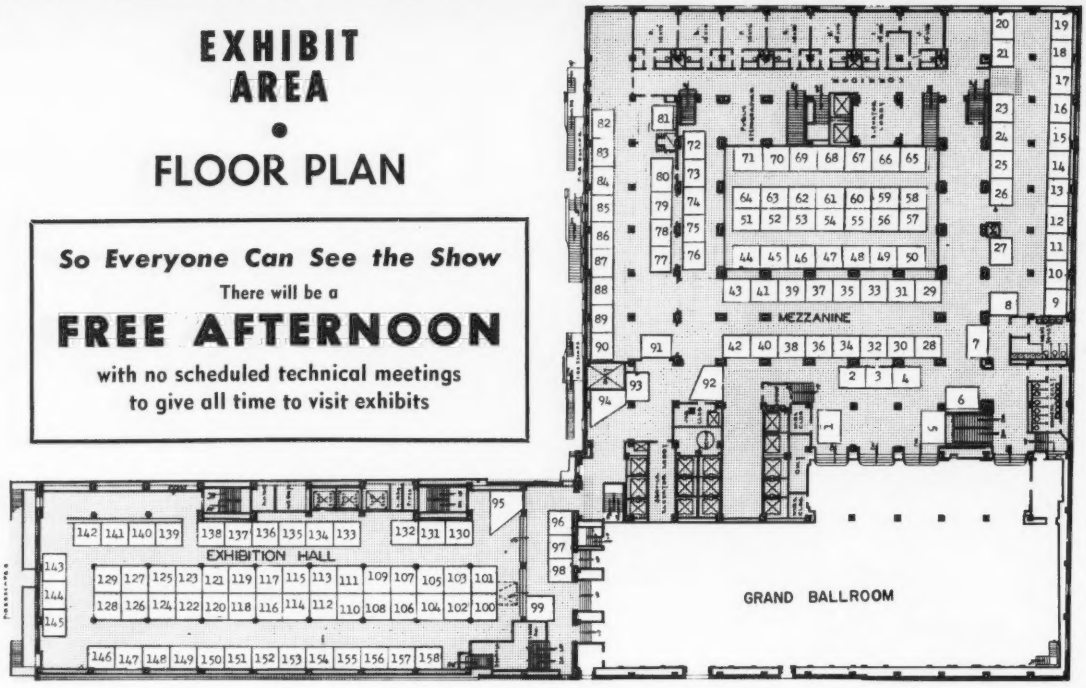
with no scheduled technical meetings
to give all time to visit exhibits



Several Thousand Get Descriptive Literature

Descriptive literature about the 1959 Corrosion Show to be held at the Sherman Hotel, Chicago concurrently with the NACE 15th Annual Conference was mailed to several thousand prospective exhibitors last month. The show, with initial floor plans calling for 160 booths, will be held in the mezzanine and exhibition hall areas of the hotel. Conference technical sessions will be held in the same general areas.

R. W. Huff, Jr., who is handling details of the show at NACE Central Office in Houston said the physical arrangements for the event are unusually good. The hotel has recently been remodeled and special provisions have been made for the speedy and efficient handling of exhibit material.

All Under One Roof

"The biggest advantage we have over some other shows," Mr. Huff said, "is that the show and the conference are in the same building. This means that no time will be lost going to and from the exhibition and that those attending the technical sessions can get to the show at all times."

Chicago's assets as a transportation center and its proximity to the booming St. Lawrence Seaway is expected to enhance the importance of the show. Many of NACE's Canadian members live in areas close to Chicago, making it convenient for them to participate in the show.

Industrial Development Rapid

The rapid progress being made along the seaway and the Great Lakes ports also is an asset. The industrial development of this part of the continent is expected to gain new impetus with the completion of the deep water channel to the Atlantic.

The March 17-19 show will be NACE's fourth exhibtion in Chicago. Each of the earlier exhibitions, in 1947, 1953 and 1955 was larger and more diversified than the preceding one. The 1959 show is expected to be larger than any of the other three.

Firms interested in the show may get complete information by writing to R. W. Huff, Jr., NACE Central Office.

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Test Code for Diesel and Burner Fuels, methods for determining physical and chemical properties of liquid fuels used to generate heat or power has been published by American Society of Mechanical Engineers. Power Test Code for Deaerators, was designed to improve performance of deaerators in main power plant condensers.

BIOGRAPHIES

(Continued From Page 76)

and is a past chairman of the Inter Society Corrosion Committee.

He is head of the chemical division, Aluminium Laboratories, Ltd, and for the past 12 years has been occupied with the corrosion behavior of aluminum. He has direct knowledge of the cost of corrosion to the chemical industry by his experience as an industrial chemist in explosives, wood pulp and copper and gold mining. He has published several papers on the corrosion behavior of aluminum and its alloys, has a PhD in industrial and cellulose chemistry from McGill University and an MS in chemical engineering from the University of British Columbia.

In addition to his work with NACE, he has been chairman of the AAAS Gordon Research Conference on Corrosion and a member of the Canadian Associate Committee on Corrosion Research and Prevention.

GEORGE E. BEST is technical adviser to the general manager of technical service, Solvay Process Division of Allied Chemical Corp. Prior to the merging of Mutual Chemical into Solvay, he was manager of technical service, Mutual Chemical Division.

In NACE, he has been active in the Baltimore Section, the Northeast Region and in national conferences. He held offices in Baltimore Section, in Northeast Region and he was a NACE director and a member of the executive committee. He currently is corporate membership chairman and a member of the awards committee.

He was a member of the technical program committee for the Eighth Annual Conference in 1952. In the 14th Annual Conference he was chairman of the Chemical Inhibitors Symposium, after serving as vice-chairman the preceding year. He is a member of technical committees T-3A on Corrosion Inhibitors and T-4D on Corrosion by Deicing Salts and author of two technical papers presented at annual meetings and published in CORROSION.

A. L. STEGNER, Tennessee Gas Transmission is the incumbent for the office of treasurer. He is a member of technical committees T-2D on Standardization Procedures for Measuring Pipe Coating Leakage Conductance, and T-7D on South Central Region Corrosion Coordinating Committee.

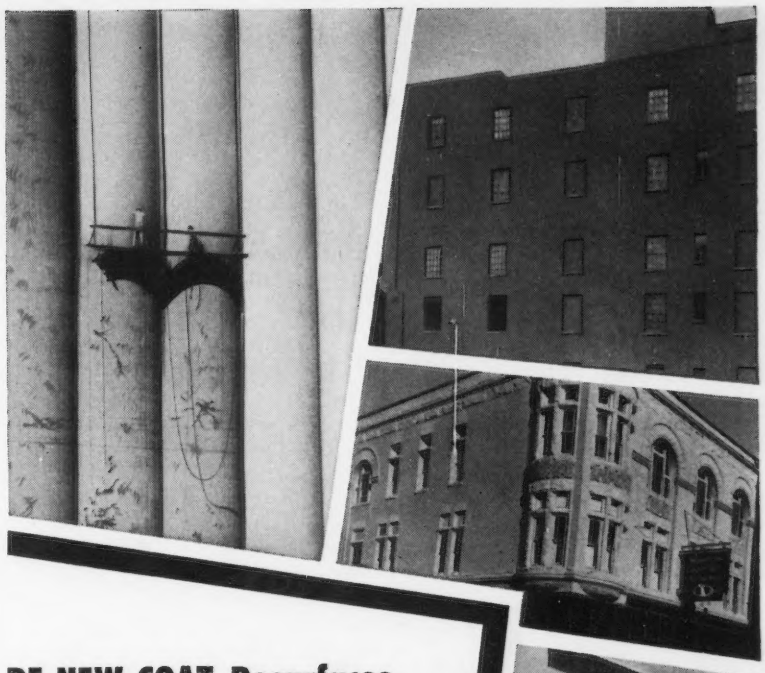
Mr. Stegner has been with Tennessee Gas Transmission since 1946 where he directs the corrosion control program and the radio communications department. Prior to military service in 1941, he was engaged in power transmission and distribution, which field he entered on graduation from Louisiana State University in 1928. He is a member of the AIEE, PIEA, and is on API committees, and corrosion committees of the Natural Gasoline Association of America.

JACK P. BARRETT, Pan American Petroleum Corp. has been active in NACE affairs since 1947, serving in technical committee work, in Tulsa Section activities, where he was a section chairman and as vice-chairman of South Central Region. Using information acquired from 13 years of work on oil field corrosion problems, Mr. Barrett has published papers covering coatings, cathodic protection and inhibitors. Since 1953 he has been research group supervisor for his firm, directing corrosion research. He is a graduate of William Jewel College in 1938 with a degree in chemistry. After graduation he worked for North American Aviation and the Kansas City water department.

EDWARD L. SIMONS, General Electric Research Laboratory was the 1956 winner of the NACE Young Author Award for a paper entitled, "Sodium Sulfate in Gas Turbines." He is now chairman of the Northeast Region and has held the posts of vice-chairman and secretary-treasurer for the region. He was chairman in 1955 of the Schenectady-Albany-Troy Section and served as section vice-chairman in 1954.

In his present position with General Electric, he supervises service work in organic chemical analysis, conducts research in inorganic chemistry and consults with members of his company's operating components on chemical and corrosion problems. He was assistant professor of the chemistry department, Rutgers University and a research scientist on the Manhattan Project. He has a PhD and an MS in physical chemistry from New York University.

GUY F. WILLIAMS, Dowell Incorporated, is assistant sales manager for his firm, which provides oil and gas well acidizing and special services, magnesium anodes for cathodic protection, and industrial chemical service. Dowell Inc. has been a corporate member since 1949 and has been active in supporting NACE as exhibitor at national conferences, as advertiser in CORROSION and as a corporate member.



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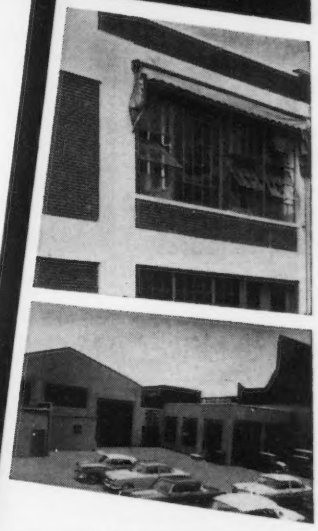
ECONOMY — Because of the several mil thickness of dense structurally strong coating, built with only one application, there is no need for a second time-consuming application.

LONG LIFE PROTECTION — Prolonged protection against surface erosion is just one of the beneficial characteristics inherent in Re-New-Coat.

WEATHER PROTECTION — Masonry structures subjected to constant erosion caused by driving rains and chemical fumes common to industrial areas are effectively protected for years to come.



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ABOUT CHICAGO CONFERENCE SYMPOSIA OFFICIALS

CATHODIC PROTECTION SYMPOSIA

Chairman L. A. Hugo, Phillips Petroleum Co., served as chairman of this symposium for the 14th Annual Conference. He is manager of his company's corrosion survey branch, engineering department. One of the early members of NACE, he helped organize the Tulsa Section and was its chairman in 1951; a national NACE director, 1951-54, and has held numerous other offices in NACE's programs. He has a BS in electrical engineering from Oklahoma A & M College and has been in corrosion mitigation work since 1938.

CHEMICAL INDUSTRY SYMPOSIUM

Chairman S. W. McIlrath, central engineering department, Diamond Alkali Co., Cleveland. He joined NACE more than 10 years ago. He has been corrosion specialist for the last four years for all Diamond Alkali Co. plants as well as chairman of the company's alkali, protective standardization program. His corrosion experience includes three years as liaison section on packaging tanks and parts for overseas shipment in the Army's Cleveland Ordnance District and seven years as corrosion engineer at the Painesville, Ohio works of Diamond Alkali. He has a BS in ChE from Fenn College, Cleveland and during 1944-46 was in the Navy Bureau of Ordnance as cognizance officer for rocket propulsion.

CORROSION INHIBITORS SYMPOSIUM

Chairman Leonard C. Rowe, was co-chairman of this symposium for the 1958 Conference. He is a senior research chemist, chemistry department, research staff, General Motors Corp. Mr. Rowe's NACE activities include work in Technical Committees T-3A and T-4D and in the Detroit Section as program chairman and member of the executive committee. He has been transportation industry correspondent for CORROSION. He has a BS and MS from Michigan State University. His work with General Motors is on corrosion activities, and on specific corrosion projects.

Co-chairman A. J. Freedman is senior project supervisor in the corrosion section, engineering research department, Standard Oil Company (Indiana), Whiting, Ind. Prior to joining Standard Oil Co., he did research in radiochemistry, reaction kinetics and separation methods at the Massachusetts Institute of Technology, Los Alamos Scientic Laboratory and the University of New Mexico.

EDUCATIONAL LECTURES

Chairman Anton deS. Brasunas has been with the American Society for Metals since March 1955 as director of the Metals Engineering Institute, Home Studies School of the Metals Industry. A member of several technical societies, his association work includes that of chairman of the Inter Society Corrosion Committee, subcommittee on Standard Definitions and Terminology. He was a founding chairman of the East Tennessee Section. He is a graduate of MIT with a ScD degree. He served as co-chairman for the Educational Lectures at last year's conference. He is author of numerous papers dealing with high temperature corrosion, and co-author of the book "Symposium of Corrosion Fundamentals."

ELEVATED TEMPERATURE SYMPOSIUM

Chairman Robert T. Foley is with General Electric Co. as corrosion chemist, general engineering laboratory. He has been active in NACE on technical committees on Corrosion Products subcommittee and as chairman of the Oil Ash Corrosion Task Group. His work with General Electric has been in the field of high temperature oxidation of metals. He has a BS in chemistry, University of Massachusetts, MS, Lafayette College, PhD, physical chemistry, the University of Texas. At Calco Chemical Div., American Cyanamid Co., he worked in physical chemistry research and he also has done research on surface reaction of silver and alloys, on the development of accelerated tests and on stress corrosion of copper base alloys.

E. W. McDowell, Jr., co-chairman, is a metallurgist in the Stainless Steel and Heat-Resistant Alloys Section of the Development and Research Department, The International Nickel Co., Inc. He is author of numerous technical papers and presently is writing the correspondence course on stainless steels for the Metals Engineering Institute, ASM. In addition to being a member of NACE and ASM he also belongs to the American Welding Society and the American Institute of Mining, Metallurgical and Petroleum Engineers.

He served on a Navy carrier in the Pacific War Theater and later as ordnance officer during World War II. At the outbreak of the Korean War, Commander McDowell was recalled into the Navy and served for three years as project leader on an atomic energy program. He is a graduate of the University of Pittsburgh with a BS degree.

GENERAL CORROSION SYMPOSIUM

Chairman W. W. Binger, is assistant chief, chemical metallurgy Division, Alcoa Research Laboratories. He has been with Alcoa since 1943 and his principal work has been in the development of aluminum alloys for application in the chemical industry. On leave from Alcoa during 1944 and 1945, he served with the Manhattan Project at the University of Chicago and at Oak Ridge, Tenn. He is the author of many papers on the corrosion of aluminum. He was co-chairman of the symposium last year. He joined NACE in 1947.

Co-chairman W. L. Mathay is senior technologist, Applied Research Laboratory, United

(Continued on Page 84)

Along the new highways . . .
ROSKOTE DOES THE JOB WITH SPEED!

Fast drying that permits overcoating or wrapping in a half hour steps up the protective coating phase of new pipeline construction on the jobs where speed is essential — along the nation's new network of highways.

A good example is this 8000 foot stretch of new 8″ pipe along the new Southside Expressway in downtown Charleston, W. Va. It was installed recently for the United Fuel Gas Company by Saul and McCallister, Inc., of Yawkey, W. Va.

This contractor found that two men, using the Roskoter for application of Roskote 612 XM cold-applied pipe mastic, could keep pace nicely with the welders. The coating specifications called for over-the-ditch cleaning, two 15 mil applications of Roskote 30 minutes apart, followed immediately by wrapping with 15 lb. perforated asbestos pipeline felt.

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A LEADER IN THE FIELD OF INDUSTRIAL COATINGS FOR CORROSION CONTROL.

Federal Officials Recognize NACE, Greet A. B. Campbell

Recognition of NACE and of its outgoing Executive Secretary A. B. Campbell has come from President of the United States Dwight D. Eisenhower, Vice-President Richard Nixon and Secretary of Defense Neil McElroy.

The association was honored during its 15th Annual Conference and Exhibition in San Francisco by telegram from the President and by letters from the Vice-President and Secretary of Defense.

Text of the President's telegram:
1958 Mar 17 AM 7:28

Greetings to the members and guests of the National Association of Corrosion Engineers on the occasion of your annual meeting and particularly to Mr. A. B. Campbell who I understand is retiring as executive secretary of the association. The work of preventing corrosion and consequent vast losses to industry has a value that is incalculable. I am sure that your association, through its research in the better ways of preserving metal, is also making a notable contribution to public safety. Best wishes for a successful meeting and many more years of fruitful service to your membership.

Dwight D. Eisenhower

Mr. Nixon expressed wishes for a successful NACE meeting and concerning Mr. Campbell's retirement said, "My very best wishes to Mr. A. B. Campbell as you pay tribute to him on the occasion of his retirement."

The role of corrosion prevention in conserving material for national defense was recognized by Mr. McElroy who said, "We are fully aware of the contributions which your association can make to national defense in research and other areas, and we welcome such interest and cooperation." He, too, extended best wishes to Mr. Campbell.

LETTERS TO THE EDITOR

March 28, 1958

The Editor of Corrosion
National Association of Corrosion Engineers
1061 M and M Building
Houston 2, Texas

Dear Sir:

May I make a plea for the return to larger size type in printing technical articles in CORROSION? I find the Technical Section difficult to read as it is now published, and the journal is appreciably less inviting as a source of information because of the "fine print" in which all articles are composed. The arduous business of deciphering the crowded sentences in technical articles is made even more painfully evident by the contrast of print used by most advertisers in CORROSION who know the value of making their message easy to read and attractive. I am not implying that any lesser emphasis on the Technical Section of CORROSION as compared with the advertising section is intentional, but we risk this impression as things now stand.

Admittedly, the use of smaller types saves money, and the economy is both desirable and necessary. But on the other side of the ledger, eyesight and time also cost a great deal, and perhaps these also should be economized. Another factor bearing on this matter is that students, who always have much to read, are conditioned to consider that anything published in small print is not important, and can be glossed over without dire consequences. Is it our intention to have

(Continued on Page 86)

CONFERENCE OFFICIALS

(Continued From Page 78)

chemistry and did graduate work in marketing and finance at Northwestern University.

J. J. IRWIN, Revere Chemical Co., registration chairman, is familiar with registration problems in the Sherman Hotel, scene of the 1959 Conference. He was registration and printing chairman for the North Central Region Meeting, October 1-4, 1957 which was held in the Sherman. He is president of Revere Chemical and started with the company in 1949.

RICHARD RUE, Insul-Mastic Inc., is program coordinating chairman. He is director of research for his firm. He has a BS in chemistry, Beloit College and has had additional courses in engineering, petroleum technology and plastics at Illinois Institute of Technology and at the universities of Illinois and Toledo. His specialty is the research and development of organic protective coatings.

L. O. RISETTER, Industrial Coatings Corp., is in charge of the ladies' program. He had the same duties for the North Central Region Meeting in 1957 and in addition was entertainment chairman for the region meeting. He is president of Industrial Coatings Corp. which he founded in 1939. Prior to this he was a salesman with the Lithcote Corp. and an engineer with the Illinois Bell Telephone Co. He is a graduate of Beloit College and attended John Marshall Law School for three years.

SYMPOSIA OFFICIALS

(Continued From Page 82)

States Steel Corp. He is now coordinating research and development activities concerned with tin mill products. Prior to this he was section leader of the chemical and process corrosion group. Before joining U. S. Steel in 1954, he had several years of experience in water treatment work. He received a BS in chemistry from Thiel College and took graduate studies toward a MS in chemistry at Carnegie Institute of Technology.

HIGH PURITY WATER SYMPOSIUM

Chairman Sherman L. Williams, General Electric Co., Knolls Atomic Power Lab., has been engaged in work on process design and coolant technology problems associated with development of nuclear power plants. He attended Cambridge University, has a BS degree from Iowa State College and an MS from Rutgers University, 1951.

MARINE CORROSION SYMPOSIUM

Chairman Franklin Watkins, director, corrosion division, Sinclair Research Laboratories, Inc. Since 1946 he has been working for Sinclair on additive synthesis and formulation of petroleum products with additives. These projects are an outgrowth of his interest, developed while with General Electric Co., in electrical transformer oils. He is an inventor, holding more than 30 patents. He specialized for many years in corrosion problems of the petroleum industry and in 1955, on leave of absence from Sinclair, acted as full-time coordinator of research on tank ship corrosion problems for API.

Richard O. Norris, section leader, corrosion section, Cities Service Research and Development Co., is symposium co-chairman. He is active in ACS, API, is a member of the API Tanker Program Committee, and of IB Corrosion Committee, Refinery Division. He holds BS, ChE, MS and PhD degrees from the University of Notre Dame.

OIL AND GAS PRODUCTION SYMPOSIUM

Chairman Jack Battle is with Humble Oil & Refining Co. as a supervising chemical engineer in the production department. He has been active in NACE since becoming a member in 1944. He is at present a member of seven technical committee organizations, is chairman of T-1 on Corrosion in Oil and Gas Well Equipment and is a past chairman of TP-1H on Corrosion of Oil String Casing. He is a registered engineer and is active in the American Petroleum Institute, American Institute of Mining and Metallurgical Engineers and the American Chemical Society.

Co-chairman W. C. Koger, Cities Service Oil Co., is head of the corrosion and oil treating section, oil production division, Bartlesville, Okla. He has been with Cities Service since immediately after his graduation from the University of Arkansas with a BS in chemical engineering in 1944. His first assignment was refinery research. In 1946 he was transferred to the company's oil production division as corrosion engineer in the West Kansas division. Mr. Koger is vice chairman of NACE Technical Committee T-1, and chairman of Task Group T-1H-1 on Oil String Casine Corrosion, West Kansas Area. He is also a member of three other working NACE technical organizations.

PAPER INDUSTRY SYMPOSIUM

Chairman Merrill A. Scheil, with A. O. Smith Corporation, since 1929, beginning as a metallurgist, he is now director of metallurgical research. He is author of several papers dealing with the metallurgy of stainless steels, stress corrosion of alloys, gases in metals, identification of non-metallics in steel with polarized light, corrosion problems in the pulp and paper industry and the metallurgy and manufacture of flash welded line pipe. He is a member of a dozen technical societies and is serving or has served in active capacity on almost all of them. He holds a BS in chemical engineering and an MS in metallurgy from the University of Wisconsin.

PIPE LINE GENERAL SYMPOSIUM

Chairman C. E. Ozanich, supervises corrosion control for Southern Pacific Pipe Line, Inc., engineering dept. Prior to joining this company in 1956, he was employed by Standard Oil Company of California, spending six years in corrosion work on pipe lines, offshore piping and tanks.

PLASTICS SYMPOSIUM

Chairman Otto H. Fenner has been associated with Monsanto Chemical Co. since 1934. He has progressed through positions as production supervisor, area supervisor, project engineer, to supervising engineer. He is quite active in NACE work, helped organize the St. Louis Section and was its chairman; co-editor of the St. Louis Section monthly paper "Corrosion Topics;" is presently chairman of NACE Task Groups T-5D-7 and T-6A-20. He is a member of five other NACE technical committees or task groups. He is a member of ACS and also is president of St. Louis Professional Chapter of Alpha Chi Sigma. He has an AB in organic chemistry from Washington University.

PROTECTIVE COATINGS SYMPOSIUM

Chairman Henry W. Foelsch, Lithcote Corp., has done research and development work in surface preparation and application of phenolics, vinyls, epoxies and furanes for interior services. He formerly was associated was A. Gusmer, Inc. and with Lithgow Corp. as vice-president. He is a member of six NACE technical organizations, T-6A, T-6A-4, T-6A-9, T-6A-12, T-6D and T-6F and is chairman of Task Group T-6F-5 on Application (of organic coatings and linings for resistance to chemical corrosion). He joined NACE in 1946.

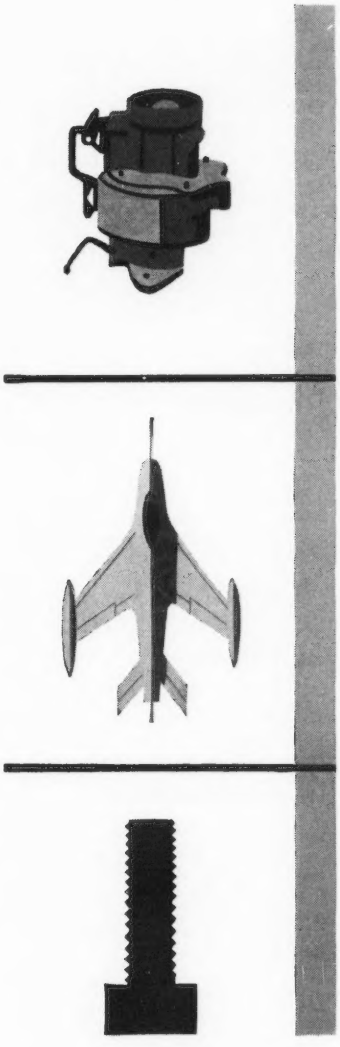
REFINERY INDUSTRY SYMPOSIUM

Chairman Edward L. Hildebrand, Humble Oil & Refining Co. has had 13 years of experience in corrosion work, including testing, material selection, welding and metallurgical studies. He has a BS in metallurgical engineering from Missouri School of Mines and Metallurgy. He has worked with the U. S. Bureau of Mines in experimental metal extraction processes. He has published articles on various subjects and instructed college courses in metallurgy. He has been active in the American Society for Metals, the American Welding Society and is a member of NACE Unit Committee T-5E on Stress Corrosion Cracking of Austenitic Stainless Steel, and of Group Committee T-8 on Refining Industry Corrosion.

UTILITIES INDUSTRY SYMPOSIUM

Chairman F. E. Kulman, Consolidated Edison Co. of New York, has long been active in NACE affairs. He is a member of 10 NACE working technical groups, almost all of which are working on corrosion problems in the utilities industry, and is temporary chairman of Technical Unit Committee T-4F on Materials Selection for Corrosion Mitigation in the Utility Industry.

Prevent corrosion & protect metals without painting



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- Alodine® 1200 for aluminum
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REPRESENTED IN PRINCIPAL INDUSTRIAL AREAS

50 More Standard Definitions Issued By ISC Committee

Fifty additional definitions recommended as standards for use in corrosion control communications have been compiled and presented for publication by the Inter Society Corrosion Committee's sub-committee on Standard Definitions and Terminology. The list has been approved for publication in CORROSION. An earlier list of 53 terms prepared by this group under Anton deS Brasunas, American Society for Metals, chairman was published in CORROSION in February, 1958.

This information was included in the reports given at the March 20 meeting of the Inter Society Corrosion Committee at San Francisco during the NACE 14th Annual Conference. Chairman Norman Hackerman, University of Texas presided over the meeting of delegates representing 11 of the committee's 32 members.

The subcommittee on membership, headed by K. G. Compton, Bell Telephone Laboratories said his group would invite the American Institute of Mining, Metallurgical and Petroleum Engineers to become affiliated with ISCC because it recently has interested itself in corrosion matters. Mr. Compton reported also that it has proved difficult to obtain names of proper persons to contact in military organizations.

Reports From Abroad Received

Reports of corrosion activity have been received by Paul Delahay, Louisiana State University, Baton Rouge, La. from correspondents in France, Germany, Italy, Japan, New Zealand, Spain and Switzerland. Additional reports are expected by the subcommittee on Relations with Foreign Organizations headed by Dr. Delahay.

It was recommended that copies of the published reports be sent to the several correspondents after publication. Foreign correspondents also will be asked to submit one-page reports concerning research projects underway in their respective countries.

F. L. LaQue, The International Nickel Co., Inc., New York said that solicitation of funds by the Corrosion Research Council has met with some success. Three advisory committees have been established on stress corrosion with Bruce Chalmers, Harvard as chairman, on surface reactions with A. T. Gwathmey, University of Virginia, chairman and electrical aspects of corrosion reactions with J. M. O'Bockris, University of Pennsylvania, chairman.

New officers of ISCC taking over at the conference were: K. G. Compton, chairman; R. R. Pierce, Pennsalt Chemicals, Philadelphia, vice-chairman. They serve for two years. T. J. Hull, NACE executive secretary also is secretary of the committee.

Reports of Delegate Members

Reports on corrosion activities of members have been received as follows:

Alloy Casting Institute

Laboratory studies were made on the physical characteristics of Alloy CD-4MCu. An iso-corrosion chart showing

(Continued on Page 87)

NATIONAL and REGIONAL MEETINGS and SHORT COURSES

1958

Oct. 5-8—Northeast Region. Somerset Hotel, Boston, Mass.

Oct. 15-17—North Central Region. Cincinnati, Ohio.

Oct. 20-24—South Central Region. New Orleans, Roosevelt Hotel.

Nov. 17-19—Western Region. Los Angeles, Statler Hotel.

1959

March 17-19—15th Annual Conference and 1959 Corrosion Show. Sherman Hotel, Chicago.

Oct. 12-15—South Central Region Meeting, Denver, Col.

1960

March—16th Annual Conference and 1960 Corrosion Show. Dallas, Texas, Memorial Auditorium.

No dates set—South Central Region Conference, Tulsa, Okla.

Oct. 11-14—Northeast Region Meeting. Huntington, W. Va.

1961

March—17th Annual Conference and 1961 Corrosion Show. Buffalo, N. Y., Hotel Statler.

Oct. 24-27—South Central Region Conference, Houston, Shamrock Hotel.

1962

March—18th Annual Conference and 1962 Corrosion Show. Kansas City, Municipal Auditorium.

October 16-19—South Central Region Conference, San Antonio, Texas.

Letters to—

(Continued From Page 84)

students subconsciously think of CORROSION as synonymous with what is unimportant?

My plea is for greater legibility in the interest of overworked eyesight, and a size type that is more commensurate with the importance of articles submitted for publication in CORROSION. This is one important way to advance the impression not only that each article bears a message well worth consideration and study, but that also the subject of corrosion is front-line news—not back page "fine print" stuff.

Very truly yours,
H. H. UHLIG
(signed)
In Charge, Corrosion Laboratory
Massachusetts Institute of Technology
Cambridge, Mass.

Comments by the Editor:

Economics demanded that we go to a smaller type, if we are to publish the needed material. The type now being used was the only one available at the publisher on the first of the year.

We are not happy with this type and are investigating alternate ones. The publisher will provide the type which we select. We shall try to establish a balance between economics and suitable type face.

50 More Standard—

(Continued From Page 86)

its resistance to nitric acid as a function of concentration and temperatures was prepared. Work was begun on an alloy resistant to hydrochloric acid but was dropped. Work continues on investigations of the pitting of stainless steels.

Studies on corrosion of alloys in aqueous media at temperatures of boiling and above continued. Iso-corrosion charts were prepared for CB-30 (18% Cr). Study was continued on the effects of ferrite-austenite structure in 18-8 castings.

American Institute of Chemical Engineers

The manual on corrosion testing is still under development. Corrosion papers were presented at meetings in June and December and four papers published.

American Society for Metals

A session on corrosion was held during the Western Metals Congress in Los Angeles in March, 1957. Corrosion papers were presented at the Chicago meeting and two other papers published.

American Society for Testing Materials

A-5 on Corrosion of Iron and Steel—Preparing 750 specimens for exposure in 1958 including flat, bent and round specimens of carbon steel, four low alloys steels and two nodular irons. They are coated with hot-dip zinc, hot-dip aluminum, electro-deposited zinc and sprayed aluminum. Exposure will be at Newark, N. J. and Kure Beach, N. C.

Reports have been made on 20-year tests of wire and 28-year exposure of hardware at State College, Pa. A new specification for zinc-coated low carbon steel armor wire was accepted by the society.

A-7 on Malleable Iron Castings—Assembling 1620 specimens of standard malleable iron, pearlitic malleable iron, nodular iron types for exposure at Newark, Kure Beach, State College, Pa., East Chicago, Ind. and Point Reyes, Cal.

A-10 on Iron-Chromium, Iron-Chromium-Nickel and Related Alloys—Expects to expose some 5000 stainless steel specimens at Newark, Kure Beach, State College, Freeport, Texas, including tubing, sheets and coil springs.

B-3 on Corrosion of Non-Ferrous Metals and Alloys—A program involving 60 specimens each of 74 alloys to be exposed at five sites. The committee also is preparing 165 couples of magnesium and a variety of other metals for Newark, Kure Beach and State College sites.

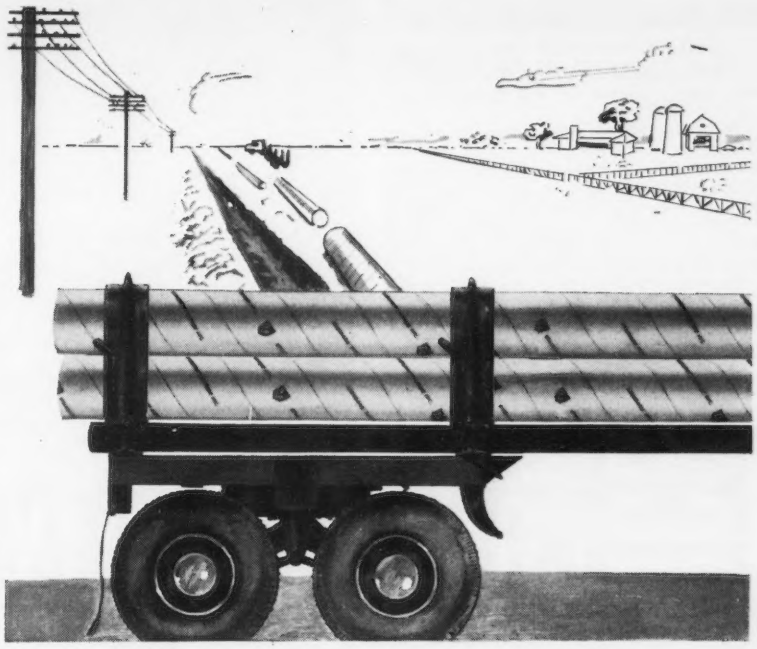
B-7 on Light Metals and Alloys, Cast and Wrought—5-year specimens of aluminum and magnesium exposed to atmosphere have been collected and data published in 1958.

B-8 on Electrodeposited Metallic Corrosion—780 chromated cadmium plated panels have been exposed at Kure Beach, New York and Rock Island, Ill.

Program 4 panels 1957 inspection data are being compiled. This project concerns values of nickel and copper strike under bright nickel and buffing effects.

C-19 on Structural Sandwich Constructions—Twenty-four sandwich panels exposed in 1955 at Kure Beach and State College were removed for examination in 1957 and a new series of 72 panels exposed at the same sites. These latter

(Continued on Page 88)



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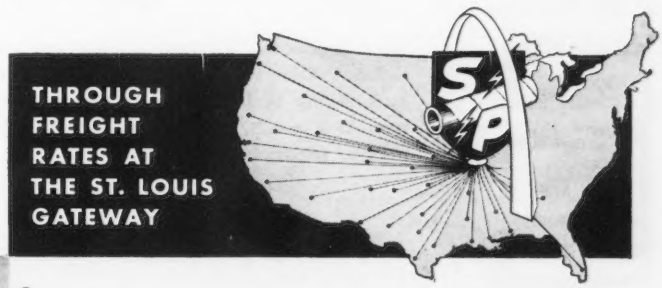

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50 More Standard–

(Continued From Page 87)

will be removed in 1958, 59 and 60. No data are available on the programs so far.

D-10 on Shipping Containers—Consideration is being given to a test to measure the corrosive staining or tarnishing characteristics of cushioning materials in contact with packages articles.

D-15 on Engine Antifreezes—A test using a reservoir equivalent to an engine block has been devised for bench corrosion tests. Twenty are being made for a collaborative testing program.

American Society of Heating and Air-Conditioning Engineers

Cooperation in work on the corrosion effects of glycol antifreezes is sought.

American Society of Mechanical Engineers

Committees are active in investigation in connection with boiler feedwater, deposits from combustion gases and high temperature steam generation. The last program, begun in 1956, has developed a conclusion that Type 347 stainless steel is not suitable for operation at the conditions existing in the 1500 F test rack.

American Society of Refrigerating Engineers

In June 1957 the ARE Research Committee Technical Task Force on Contaminants conducted a conference at which papers were presented on internal corrosion in refrigerating systems.

Papers on corrosion were presented at the Chicago and Miami meetings.

American Welding Society

The high alloys committee is working on corrosion problems involved in the welding of nickel-base and nickel-containing high-temperature alloys, stress relieving of stainless steel, heat and corrosion resistant castings, welding of stainless steels. Test racks consisting of 24 specimens of various stainless steels in the as-welded and in a variety of heat treated conditions are being exposed in industrial sites where materials so welded are in use. The aim is to find media which do and do not promote intergranular corrosion.

The Electrochemical Society

Thirty-two papers on corrosion were presented at two meetings during 1957.

National Association of Corrosion Engineers

Work of the association in holding five regional and one national meeting, nine short courses or tours; publication of 25 technical committee reports, activation of two new technical group committees on refining industry and marine biological deterioration and 84 new committee activities was reported by E. C. Greco, chairman of the NACE Technical Practices Committee.

National Bureau of Standards

The Corrosion Section of the bureau originated three papers on corrosion fundamentals. A stress corrosion of metals research project sponsored jointly by the Corrosion Research Council and the bureau was started during the year.

Two papers on pitting were prepared, one on galvanic corrosion and the NBS Circular C579 on Underground Corrosion published, summarizing 45-year studies. A project on the reactions of free radicals at the surface of metal single crystals was started. Other projects include corrosion of aircraft alloy, fly ash corrosion of stainless steels and stress corrosion of stainless steels.

National Research Council

Publication of the Prevention of Deterioration Abstracts continued.

Associate Committee on Corrosion Research and Prevention, National Research Council of Canada

A report has been prepared on one and two-year results on atmospheric corrosion of 11 metals at eight sites. Included are aluminum, low alloy steel, copper-bearing steel, copper-nickel steel, stainless Types 302, 316 and 430; magnesium alloys.

Zinc and aluminum-sprayed metallized steel panels are expected to go out in 1958 to exposure sites.

A survey of practical and theoretical corrosion work underway in Canada was prepared.

Society of Naval Architects and Marine Engineers

The Ship Technical Operations Committee is planning a research project on protective coatings, fouling and corrosion. Three papers on corrosion were presented at sectional meetings during 1957.

•

Milton A. Glaser, Midland Industrial Finishes Co., Waukegan, Ill. was the featured speaker at a May 13 meeting of Midland Coatings Society, Midland, Mich. Mr. Glaser's discussion titled "Modern Organic Finishes," covered silicones, epoxies, urethanes and applications of finishes in various industries.

WHEN IT COMES TO SERVICE

COME TO REILLY

Dick Renshaw is well known to all Reilly Enamel users because he heads up Reilly's Hot Enamel Field Service Group.

He is a praetical Corrosion Engineer and has an intimate knowledge of the composition of enamel and of the techniques of its manufacture and use. As a result, his capabilities are held in high esteem throughout the industry.

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THESE RAPT STUDENTS at Cullen Junior High School Houston, were among the hundreds who inspected exhibits at the school's science fair. A high order of intelligent interest was reported by teacher-sponsors of the event. Parents visited the fair in numbers not previously experienced for any other similar school activity. At left is E. C. Greco, United Gas Corp. Shreveport speaking to an assembly of students at the school on the value of education in the sciences.

Greco Speaks at Science Fair Program

Interest of both students and parents in 157 projects related to the sciences amazed teachers at the Ezekiel W. Cullen Junior High School Science Fair. The school is located in Houston. It was the first such event held by the school and science teachers were greatly encouraged by the high degree of interest shown in the displays by the student and their parents. More than 600 parents crowded through the school's library on the night of May 1 to see the displays, which ranged from astronomy through zoology. There was an encouraging number of projects in chemistry and in physics, especially in certain aspects of the atomic energy satellite programs.

Edward C. Greco, United Gas Co., Shreveport, Louisiana chairman of the NACE Technical Practices Committee, who has been interested in student science education in his own state for many years, spoke to some 350 students present to see awards made to winners of first, second and third places for excellence in the several divisions of the fair. Mr. Greco enumerated some of the advantages and prerequisites of a career in science and emphasized the importance of scientific achievements in the nation's race for survival with the Soviet Union.

Mrs. Alma Coats, Houston, an industrial chemist who is temporarily teaching chemistry at the school, said most of the displays came from girls and boys in the eighth and ninth grades, with a few from the seventh. Mrs. Coats teaches ninth grade science, with emphasis on chemistry.

According to the science teachers in the schools, the degree of interest in science that has been generated recently among the students and which has been exemplified by their choices of electives in science over certain catch-all course in the humanities, has demonstrated that the latent capacity for scientific achievement among the students needs only to be awakened. Assistance given the school by the Houston Engineering and Scientific Society and Houston Section of the National Association of Corrosion Engineers has been helpful in adding new interest in scientific studies.

Awards were given students with exhibits at the fair as follows: Physics, Lee Murdy, first; Margie Barker, second; Bob Pravan and Norman Robinson, third.

GLYN BEESLEY, left, chairman of North Texas Section NACE is shown here chatting with Ellis Glenn, one of the 300 future engineers attending the annual dinner sponsored by the Engineers' Club of Dallas. North Texas Section was among the engineering organizations sponsoring the attendance of high school students going into engineering.

Niagara Frontier Section is one of the donors to the 1958 Science Congress of Western New York held April 19 at Buffalo Museum of Science. More than 600 entries from 55 schools were displayed, about 50 percent more than were shown in the 1957 congress.

Teche Short Course Program Completed

The Corrosion Control Short Course at Southwestern Louisiana Institute, Lafayette, La., June 4-6 is a principal spring project of Teche Section. Final touches on the course were discussed at the April 24 meeting of the section at the Petroleum Club when 16 members and eight guests heard Kline Grigsby, president, Grigsby Brothers, Inc., speak on "Internal Plastic Coatings."

Prior to the meeting, short course committee chairmen met. A partical list of titles of papers and speakers for the short course follows: "Corrosion of Oil and Gas Equipment in Offshore Installations," by C. J. Fritts, Socony Paint Products Co., Houston; Management's Attitude Toward Corrosion and its Control," by S. G. Kershner, vice president and general manager, Texas Pipe Line Co.; "Fundamentals of Cathodic Protection and Soil Box Demonstration," by A. W. Peabody, Ebasco Services, New York, N. Y.;

"Copper Ion Displacement Testing of Corrosion Inhibitors," by M. A. Luby, Tretolite Co., St. Louis, Mo.; "Practical Uses of Holiday Detectors," by Ned C. Stearns, D. E. Stearns Co., Shreveport, La.; "Plastic Materials for Corrosion Control," by J. E. Rench, Napko Corp., Houston; "External Casing Corrosion," by Wayne A. Johnson, Corrosion Rectifying Co., Houston; "Gasoline Plant Corrosion," by M. J. Olive, Arkansas Fuel Oil Corp., Shreveport, La.; "New Concepts of Corrosion Control," by Norman Hackerman, University of Texas, Austin; "Internal Plastic Coatings," by B. P. Goodman, Tube-Kote, Inc., Houston; and "Concentric String Completions—Use in Corrosion Control of High Pressure Condensate Wells," by Lee R. DeRouen, Union Oil & Gas of Louisiana, Lake Charles, La.

W. H. Stewart, Sun Pipe Line Co., past president of NACE will present a talk on the "History of NACE" to the group.

Oklahoma Youth Sent To National Science Fair

Ludy Harman, 544 North 12, Ponca City, Okla. was the exhibitor chosen to represent the Central State Science Fair at Edmond at the National Science Fair, Flint Mich., May 7-10. South Central Region NACE made a contribution to the Oklahoma Central Science Service in 1957. This service has charge of science fair competitions in Oklahoma.

HYDROGEN ABSORPTION, EMBRITTLEMENT and FRACTURE of STEEL

By Arnold E. Schuetz, Research Department, Bridgeport Brass Company, Bridgeport, Conn. and W. D. Robertson, Hammond Metallurgical Laboratory, Yale University, New Haven, Conn.

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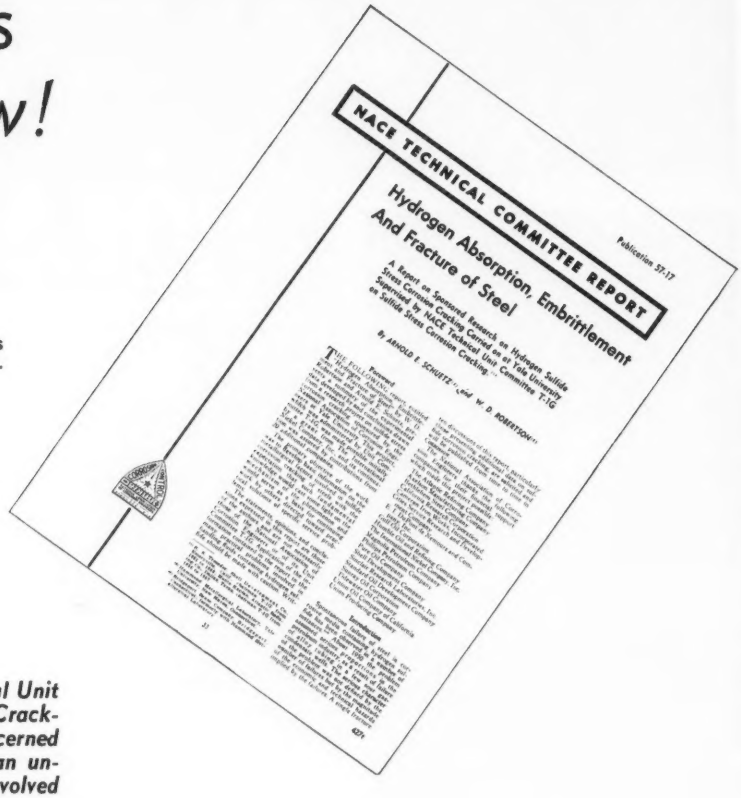

This 24-page illustrated report is replete with figures and tables on this basic research project's findings.

Basic Facts on Mechanism of Hydrogen Sulfide Stress Corrosion

The findings of a 4-year inquiry into the fundamental reactions involved in the so-called spontaneous fracture of steel as a result of hydrogen absorption in the presence of sulfides.

This project, supervised by NACE's Technical Unit Committee T-1G on Sulfide Stress Corrosion Cracking, was financed by industrial firms concerned with this problem in the expectation that an understanding of the fundamental reactions involved would lead to a solution.

Data in this report are expected to be useful not only in immediate steps to reduce the losses due to spontaneous failure but also as a foundation for subsequent inquiries into phenomena associated with hydrogen absorption and embrittlement of steel.

To: T. J. Hull, Executive Secretary
National Association of Corrosion Engineers
1061 M & M Bldg., Houston 2, Texas

Publication No. 57-17

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If you are concerned with operation of equipment subjected to hydrogen sulfide environments or are manufacturing equipment for service in this environment you will want a copy of this report.

Another Contribution of NACE to the Understanding of Corrosion Processes

GENERAL NEWS

NACE Members Prominent In Appalachian Course

Members of the National Association of Corrosion Engineers are numerous among the persons scheduled to give instruction during the Third Appalachian Underground Corrosion Short Course. The course, to be held June 10-12 at West Virginia University's School of Mines, Morgantown, has been endorsed by the American Water Works Association and the National Association of Corrosion Engineers.

Five classes of information are to be presented. Three subdivisions of fundamentals: Basic, intermediate and advanced; coatings, power and communications, water and special topics. Students will have the option of choosing classes of special interest from among concurrent classes. To be discussed are cathodic protection, microbial deterioration, field practices, lead sheath cable corrosion, instrumentation, transmission line corrosion, electrolysis switches, anodes, rectifiers, bonding and grounding, plastic pipe, well casing corrosion, various kinds of coatings and tape.

The $10 registration fees includes a copy of the proceedings. Lodging and meals for men are available at $6.12 a day in the New Women's Dormitory. Preregistration is not nacessary.

Study of Russian Is Aim Of New Organization

Means of increasing the ability of scientists in the West to read and understand Russian are being explored by Pergamon Institute, a foundation organized in England and the United States for the purpose of making translations of Russian technical works available to English-speaking scientists. It is estimated that fewer than one percent of scientists in England and the United States are fluent in Russian.

Means of improving language instructions in Russian are to be explored during this summer. The institute also is assisting in translation of important Russian books on science, technology and medicine, including numerous works on mechanics, physics power systems, space and gravity theory, ferromagnetism and chemistry, engines, mathematics.

The institute undertakes to supply on request translations of Russian works into English on a cooperative cost-sharing basis. Cost of translation will be divided among all who order the translation during a six-month period. Lists of articles and books under translation are available on request.

Bibliographical information will be supplied, and critical evaluation of scientific work in the Soviet orbit will be attempted on request by the institute's staff. Books and journals published in Soviet orbit countries will be supplied on microfilm.

Part-time translators are needed and financial assistance is solicited.

•

The Ten-Year Index to CORROSION, 1945-54, indexes over 3500 pages published in those years.

Technology History Group Schedules First Meeting

The Society for the History of Technology, which will investigate and record the history of technology has been formed by a group of scholars headed by Melvin Kranzberg, Case Institute of Technology. The society will sponsor meetings and begin publication of a quarterly journal "Technology and Culture" in the fall of 1959.

The society is co-sponsor of a meeting of the Humanistic-Social Division of the American Society for Engineering Education at Universit yof California, Berkeley June 16-17. Four technical papers will be presented.

BOOK NEWS

Nondestructive Testing Symbols. 16 pages, 6 x 9 inches, paper. March 5, 1958. American Welding Society, 35 West 39th St., New York 18, N. Y. Per copy, $1.

Symbols used for specifying nondestructive tests for radiographic, magnetic particle, penetrants and ultrasonic testing are detailed. They can be combined with welding symbols.

Rolling of Metals. R. B. Palme and C. W. MacGregor. 100 pages, 8½ x 11 inches, Paper. 1958. American Society of Mechanical Engineers, 29 West 39th St., New York 18, N. Y. Per copy, $5.

A report of the ASME Research Committee on Plastic Flow of Metals, summarizing a project conducted at the Massachusetts Institute of Technology. Contact stress distribution in the cold rolling of thick bars of aluminum, copper and low carbon steel is reported. Tests revealed occurrence of a marked pressure peak near the entry to the contact arc and frequent occurrence of two distinct pressure peaks, one near the entry and one near the exit of the contact arc. Illustrations and graphed data are given in 44 pages.

NACE Members Take Part In Meeting of AIEE

L. S. Vandelinder, Union Carbide Chemicals Co., South Charleston, W. Va. presided over a cathodic protection session May 13 during the East Central District meeting of the American Institute of Electrical Engineers at Huntington, W. Va. Presented during the session were "Cathodic Protection of Underground Structures, B. Husock, Harco Co., and "A Demonstration of Electrochemical Corrision Reactions," G. C. Cox, consultant.

AISE Meeting Scheduled

The American Association of Iron and Steel Engineers will hold its 1958 Iron and Steel Exposition and Convention at Cleveland Auditorium, September 23-26.

5-Paper Symposium On Tanker Corrosion Scheduled by API

A five-paper symposium on corrosion control inside oil tankers is scheduled for Monday, June 9 during the Annual Tanker Conference, American Petroleum Institute Division of Transportation at Greenbriar Hotel, White Sulphur Springs, W. Va. The papers cover experience with tank coatings, application of cathodic protection, use of soluble inhibitors in clean oil tankers, deoxygenation of ballast water and corrosion control form the viewpoint of the seagoing officer.

The symposium consists of the following papers:

MSTS Experience With Tanker Coatings, Capt. Dillon R. McMullen, Director, Tanker Division, Military Sea Transport service, U. S. Navy, Washington, D. C.

Investigation and Application of Tanker Corrosion Control, Arthur J. Coy, BP Tanker Co., Ltd., London.

Corrosion Control by a Product-Soluble Inhibitor in Clean Oil Tankers, W. N. Damonte, Marine Dept., Sinclair Refining Co., New York; F. M. Watkins, Corrosion Division Sinclair Research Laboratories, Inc., Harvey, Ill.; T. T. Wilkinson, Superintendent Engineer, Sinclair Refining Co., New York.

Reduction of Tanker Ballast Space Corrosion Rates by Deoxygenation of the Ballast Water with Sodium Sulfite, J. R. Caldwell, Gulf Research and Development Co., Pittsburgh.

Corrosion Control from the Viewpoint of the Seagoing Officer, C. L. Hosch, Esso Shipping Co., New York.

PERIODICALS

Reactor Fuel Processing. 36 pages and cover, 8 x 10¼ inches. Quarterly. February 1958, Vol. 1, No. 1. Prepared by Argonne National Laboratory, USAEC. Subscription: Domestic, per year $2; foreign, $2.50. Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.

Data are given in a special section on corrosion of materials found suitable in and others unsuitable for processes involved in processing reactor fuel. Corrosion test data are given for the several processes in use.

Reactor Core Materials. 40 pages, 8x10¼ inches, paper. Quarterly. March, 1958, Vol. 1, No. 1. Prepared by Battelle Memorial Institute for USAEC. Subscription: Domestic, per year, $2; foreign, $2.50. Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.

Corrosion of cladding materials is covered and documented. Data are given on zirconium, aluminum, niobium, molybdenum, chromium, nickel; corrosion mechanisms of fuel alloys; metal-water reactions.

Equipment Services NEW PRODUCTS Materials Literature

Chains

Acco X-weld Type 321 stainless steel chain made by American Chain Division, American Chain and Cable Co., Inc., York, Pa., is described in its data sheet DH-169. The chains are useful in acid pickling operations and others involving sulfuric and nitric acids at high temperatures.

Conduit

Kraloy Plastic Pipe Co., 4720 East Washington Blvd., Los Angeles 22, Cal. is making polyvinylchloride pipe with inside diameters to conduit specifications. Installation costs of this semi-rigid conduit are about half that of metals.

•

Electric-Flex Liquatite flexible wiring conduit, consisting of square locked galvanized metal tubing with an extruded vinyl plastic cover is described in a specification sheet LT 110 available from Electric-Flex Co., Roselle, Ill.

Coatings—Organic

Charcote CIC-21, a combination primer-coater protective rubber coating made by Charleston Rubber Co., Stark Industrial Park, Charleston, South Carolina has outstanding qualities of resistance to fumes, salt spray and underfilm creep, manufacturers claim. Five ingredients are included in the material to give it resistance to corrosives. It adheres tenaciously to steel, bronze, aluminum, stainless steel and galvanized iron. Illustrated catalog sheets describing properties, application and other data are available.

•

Prufcoat Vinyl-Weld Primer P-62, formulated to tolerate moisture on damp metal surfaces, makes application of vinyls feasible when moisture conditions otherwise would prevent. It may be applied by all conventional methods. Bulletin 018 which gives complete information is available from Prufcoat Laboratories, Inc., 6 S Main St., Cambridge 42, Mass.

•

Heat Indicating paint which changes from royal blue to chalk white at about 585 F can be used for immediate detection of hot spots on internally insulated steel vessels and piping, according to manufacturers, Humble Oil & Refining Co., P. O. Box 2180, Houston 1, Texas. It gives long life at temperatures up to 250-350 F.

•

Duracin Series 100, Pittsburgh Plate Glass Company's thermosetting acrylic baking enamels have been supplemented by new series 200 and 300 resins. The 200 series is suitable for interior use only while the 300 series, not equal to the other two in durability is said to be better than alkyd amine finishes.

•

Vinyl Plastisols are now being used to line drums for corrosive chemical shipments by Jones & Laughlin Steel Corp.

•

Polysulfide Liquid polymer base sealing compounds suitable for sealing integral fuel tanks and pressurized cabins of jet aircraft are made by Products Research Co., 3126 Los Feliz Blvd., Los Angeles 39, Cal.

•

Granodine Phosphate Coatings of American Chemical Paint Co., Ambler, Pa. are described in a new 4-page brochure available on request.

Coatings—Metallic

Niphos Process of coating mild steel with a layer of stainless steel to give it corrosion resistance approaching that of stainless is described in a bulletin available from Tube Reducing Corp., P. O. Box 959, Passaic, N. J.

Fuel

Hot Gas Turbine exhaust will be used instead of air for combustion in a boiler at Continental Oil Company's Lake Charles, La. refinery to use the tremendous amount of heat which otherwise would be wasted in the exhaust gases.

•

Char remaining after extraction of gases and other volatile constituents of coal will be burned under a boiler developed by the Babcock and Wilcox Co. The char, which is said to have about the same heat value as coal, is not a premium fuel and can be used for power generation.

Fume Depressants

Akweons No. 250, an acid fume depressant made by Swift & Co., Technical Products Dept., 1800-165th St., Hammond, Indiana greatly reduces acid fumes in pickling and electrolytic operations. It has no corrosion-inhibiting properties, however.

Gases

Chemetron Corp. has been selected as the new name of National Cylinder Gas Co.

•

New Nitrogen supply facilities have been put into operation by Linde Co., Div. of Union Carbide Corp. in Houston and Tulsa. Liquid nitrogen will be delivered in tank trucks.

•

Linde Argon delivered as a liquid is guaranteed to be 99.995 percent pure.

Inhibitors

No-Wrap Rust Inhibitors, small discs impregnated with a volatile corrosion inhibitor can be used to protect small parts in transparent containers without interfering with visibility. In typical packaging practice, the discs are placed with the product in a polyethylene bag, which is then heat sealed. They are available from Chippewa Paper Products Co., Inc., 2425 S. Rockwell St., Chicago.

Instruments

Dissolved Oxygen Analyzer, which continuously measures dissolved oxygen in high purity water, detecting traces as low as one part per billion is being marketed by Beckman Process Instrument Division, 2500 Fullerton Rd., Fullerton, Cal.

•

Illinois Testing Laboratories, Inc., 420 N. LaSalle St., Chicago 10, Ill. has developed a dew-point tester using the principle of varying pressure, rather than temperature. The Alnor Dewpointer is described in an 8-page bulletin available on request.

•

Soil Redox Probe instruments, used to determine the reduction-oxidation potentials of soils are designed for field use at pipe depths by Deuber Laboratories, 114 East 32nd St., New York 16, N. Y. Readings of the probe are made with a milliammeter and the degree of soil corrosiveness is indicated without reference to a corroding structure, making the instrument useful for soil surveys.

•

Model R Vidigage, a rack-mounted unit is designed for quality control use in gaging, recording and detecting laminar flaws. The device is available from Branson Instruments, Inc., Stamford, Conn.

•

Anderson Physical Laboratories, 609 South Sixth St., Champaign, Ill. has published an extensive near infrared spectra. The spectra, covering all classes of organics and some inorganic compounds in the 0.7 to 3.2 micron range will be made available to all spectroscopists. A bulletin is available.

•

Range Selector Electrobalance, which will weigh pieces as thin as 0.25 mil to 0.02 percent accuracy are available from Cahn Instrument Co., 14511 Paramount Ave., Paramount, Cal. The balance accommodates pieces in the range 1-100 mg.

Laboratories

Robertshaw-Fulton controls will construct a fifth research and development center on a 20-acre site 14 miles from Philadelphia in the town, King of Prussia. About 100 will be employed.

Lubricants

Sunvis HD 340, a new type railroad Diesel engine lubricating oil is said by manufacturers, Sun Oil Company to have more alkaline reserve for protection against corrosion by fuel sulfur, than other oils and other desirable attributes.

(Continued on Page 93)

NEW PRODUCTS

(Continued From Page 92)

Metals—Ferrous

Techalloy Co., Rahns, Pa. is fabricating wire and rod from ½-inch to .002-inch diameters and thin strips, in widths up to 6 inches using Inconel 702, Incoloy T and 805 and 901.

•

Direct Reduction of iron ore to pig iron or semi steel is practical using a new process developed by Strategic Materials Co. and Koppers Co. It is not immediately competitive with iron and steel from conventional furnaces and requires relatively inexpensive electrical power. The patented method is relatively simple.

•

Colored Stainless Steel is now possible using a new coloring process developed by Electro Metallurgical Co., Division of Union Carbide Corp. The Permyron process permits large parts to be severely formed without impairing surfaces. Many colors, including black can be produced. Resistance to corrodents is not materially affected.

•

New High Temperature Alloys have been designated D-979 and AF-71 by Allegheny Ludlum Steel Corp. They will be useful for jet engine and gas turbine applications and steam turbine components, among others.

Metals—Non-Ferrous

J-1300, a precipitation hardening iron-based alloy developed by the Metallurgical Products Dept. of General Electric Co., Detroit is especially effective in the range 1300-1350 F. It is expected to have wide application in jet engines and similar units.

•

Hastelloy B, C and F and titanium have been rolled successfully in clad plate form by Lukens Steel Company. Samples of the new sheets were displayed at the recent NACE show in San Francisco.

•

Columbium at 99.6 percent purity is commercially available from Electro Metallurgical Co., Division of Union Carbide Corp., Niagara Falls, N. Y.

•

Carpenter Lapelloy C, developed by The Carpenter Steel Company, Reading, Pa. for jet engine parts has more homogeneous structure and uniform fabrication behavior than conventional Lapelloy. It is used for highly stressed parts used at temperatures up to 1200 F.

•

Ampco Grade 8 Alloy, an aluminum bronze developed by Ampco Metal, Inc., 1745 South 38th St., Milwaukee, Wis. can be used successfully in conditions which promote stress corrosion cracking of other aluminum bronzes, the company says. The material, which has been tested several years in numerous environments does not have to be stress relieved after fabrication. Detailed data are available from the company.

Plastics—

Cadillac Plastic and Chemical Co., 15111 Second Ave., Detroit 3, Mich. has published a 64-page catalog of plastic sheets, rods, tubes, films and lay-flat tubings, which the firm has in stock. Weights, color ranges, textures, purchasing specifications grades and prices are given. The firm has warehouses and offices through the Middle West, the Southwest and West.

•

Tube Turns Plastics, Inc., Louisville, Ky., has granted manufacturing rights of the Hendry injection molding process and equipment to BTR Industries, Ltd., London, England. Tube Turns Plastics manufacture injection molded unplasticized polyvinyl chloride fittings and valves for industrial and commercial piping systems, especially for corrosive service.

•

Halocarbon Products Corp., 82 Burlews Court, Hackensack, N. J. is marketing Fluoropack, a non-jelling, putty-like material which is moldable under pressure to the contour of any stuffing box. The new corrosive resistant packing material is composed of finely divided Teflon compounded with a blend of special fractions of Halocarbon polychlorotrifluoroethylene oil. Service temperatures range from —40 to 350 F.

•

Swepco Tube Corp., Clifton, N. J., and Tube Turns Plastics, Inc., 2929 Magazine St., Louisville 13, Ky., are manufacturers jointly, of unplasticized polyvinyl chloride lined fittings and pipe. The pipe will be made by Swepco; the fittings manufactured by Tube Turns Plastics. The later company will market the product. Brand name will be Swepcore UPVC lined pipe.

•

JALboy, a new plastic-and-steel returnable container for shipment of corrosive chemicals is now being produced and marketed jointly by the container division of Jones & Laughlin Steel Corp., 3 Gateway Center, Pittsburgh 30, Pa. The container consists of a polyethylene liner in a steel drum, a standard 14-gallon, and a heavy duty 13-gallon drum.

•

Apex Reinforced Plastics, division of White Sewing Machine Corp., Washington and Elm, Cleveland, Ohio manufactures a fiber glass epoxy resin in impregnated bottle for high pressure storage of liquids and gases. The bottle was designed for military use, but the firm feels it has commercial possibilities. Up to 50 percent saving in weight is claimed over metals. Pressures range from 100 to 5000 psi.

•

Resistoflex Corp., Roseland, N. J., is expanding its facilities for fabricating Fluoroflex-T (Teflon) pipe, pipe fittings, expansion joints and related items for high temperature, corrosive service. The new 30,000-square-foot extension will be added to the company's main plant at Roseland.

•

Chemfab Corp., 40-30 23rd St., Long Island City 1, N. Y. is manufacturer of tubing and equipment with high mechanical and dielectric strength at subzero and elevated temperatures and with dimensional tolerances of .001-inch. Produced in tubular and other forms, the new materials are already being used in aircraft electronic fuel gages and as rigid conduits for corrosives.

(Continued on Page 94)

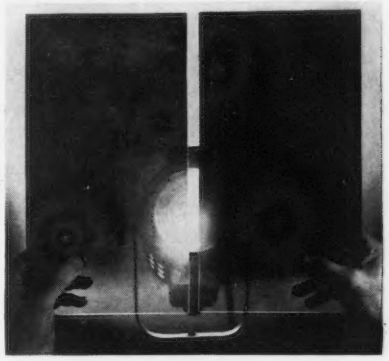
Spraying tips for

FIGHTING CORROSION

Hot spray gives more effective protection

An adequate, uniform film-build is all important for surfaces subject to exposure and wear.

Here's why hot spray offers more effective protection. When you heat paint, you can apply higher solid-content materials for heavier coats—and reduce the shrinkage that draws film thin during drying. Generally speaking, *one* hot-sprayed application covers better than *two or more* coats by other conventional methods.



Demonstration on two glass panels proves how heavier film-build — thus, greater protection — is possible with hot spray. Left panel shows paint applied to its maximum film thickness by cold-spray method, and right panel shows how much heavier the same paint can be applied by DeVilbiss Hot Spray Method.

Heated materials should be applied at low spraying pressures with slow deliberate strokes—close to the surface to achieve a full, wet coat for maximum protection and reduce overspray.

Compact DeVilbiss Portable Paint Heater provides a convenient means of carrying hot spray to the job. Included in the outfit is an exclusive, heat-jacketed hose that keeps your protective-coating material hot right up to the gun.

If you have a corrosion problem that coating can solve, the DeVilbiss spray method more than likely will reduce the cost of application. Call your nearest DeVilbiss representative today and discuss your situation with him. *The DeVilbiss Company, Toledo 1, Ohio; Barrie, Ontario; London, England. Branch Offices in Principal Cities.*

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DEVILBISS

NEW PRODUCTS

(Continued From Page 93)

Viton, synthetic rubber, a new fluorine-containing elastomer which is resistant to oils, fuels and solvents at temperatures above 400F, is being made in a new plant of the E. I. duPont de Nemours and Company, at Deepwater Point, N. J. Viton is a linear copolymer of vinylidene fluoride and hexafluoropropylene, containing about 65 percent fluorine by weight. DuPont calls its development a major break-through in elastomer chemistry.

•

Trilok, a Saran and polyethylene woven fabric for filter processes, is made by the National Filter Media Corp., 1717 Dixwell Ave., New Haven, Conn. Primarily used as a filter media support and drainage member for wet process filters, the material has possible uses, in honeycomb, sandwich form, where temperatures are moderate and corrosion severe, as mist eliminators, or entrainment separators in vacuum towers, distillation equipment, gas absorbers, scrubbers, evaporators and other like equipment.

•

The Chemtrol valve operator is made of molded plastics designed for use in plastic piping carrying corrosive fluids. The entire assembly is made of plastic. Specific plastic materials selected in making the apparatus can be varied according to use requirements. Address of the manufacturer is Chemtrol, a division of Tapered Air Products, 10890 Stanford Ave., Lynwood, Calif.

Pumps

General Ceramics Corp., Keasbey, N. J., has published a brochure giving a table of physical properties and performance of its armored chemical ceramic vacuum pumps and compressors.

Rectifiers

International Rectifier Corp., El Segundo, Calif., has published a booklet aimed at helping suppliers in the design and procurement of military rectifiers. The illustrated brochure also shows and explains the company's products, including solar energy converters and photo cells such as were used in the first automatic camera aperture actuators.

Solvents

Dowell, Inc., Box 536, Tulsa 1, Okla., has published a 4-page illustrated brochure describing the high-pressure jetting of regenerative air preheaters. Streams of water at 2000 psi are forced through specially designed jet heads which blasts deposits off the rotors in the preheater. Before the jet method was developed, rotors were scraped by hand or were replaced.

Unions—Insulating

Universal Controls Corp., P. O. Box 13122, Dallas 20, Tex., manufacture insulating meter nuts and pipe unions for industrial and domestic use. Uses are on water heaters, water softeners, electroplating equipment, dairy machinery, laundry machinery, air conditioning, natural or manufactured gas systems, food processing equipment, chemical industry, electric furnace cooling systems and others. They have nylon inserts to insulate pipe joints; however, liquid in the pipe never contacts the nylon; a tough rubber gasket makes the seal so cracks in the nylon will not cause leaks. Outside shell and fittings of the union are of galvanized malleable iron or brass. Meter nuts and union shells which hold the nylon inserts are steel, heavily zinc electroplated inside and out.

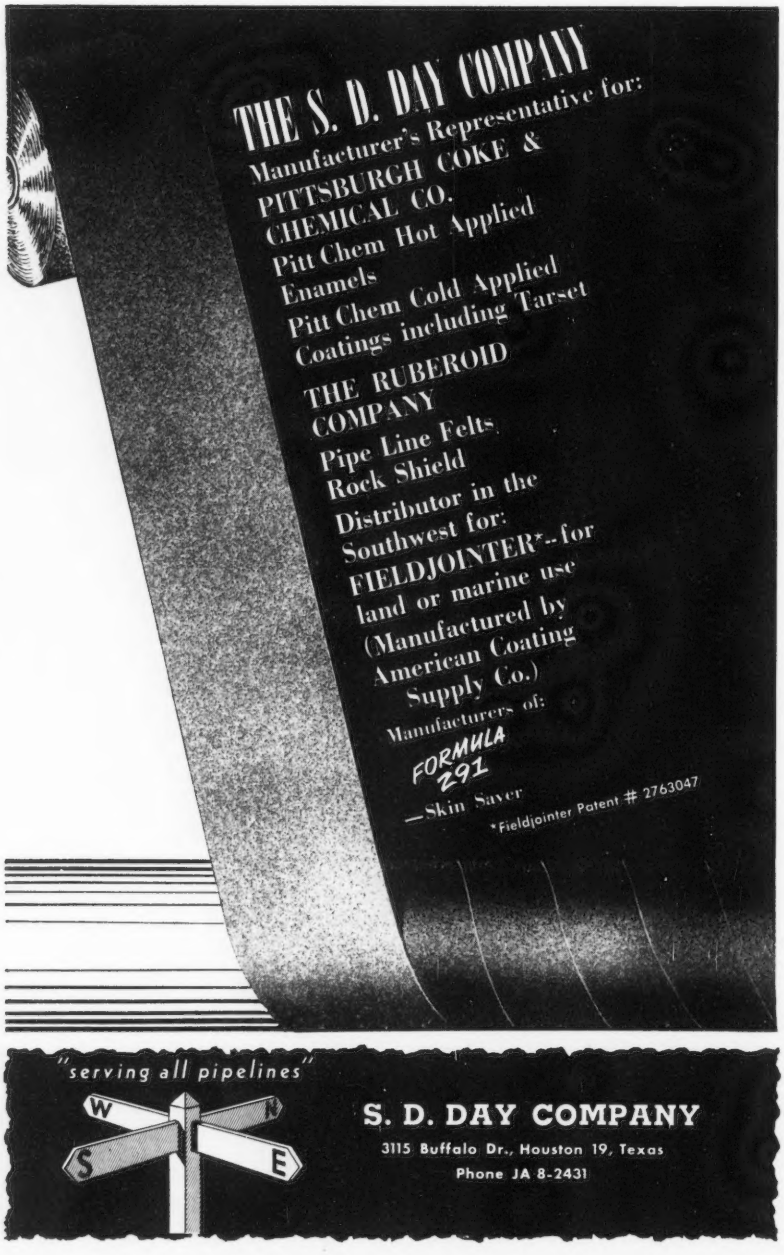
Valves

Cooper Alloy Corp., Hillside, N. J. has designed a fire protection gate valve which will shut off flows of combustibles carried by process piping and prevent the feeding of a fire outbreak in plants. The valve has a fusible link which will melt at 160F, releasing the spring which closes the valve. The valve is designed with petroleum producers, acid plants, pharmaceutical firms, film processors and liquid combustible producers in mind.

•

E. I. duPont de Nemours & Co., Wilmington, Del., has designed a closure face for valves controlling flow of tetraethyl lead in gasoline blending plants and other installations. The new material for the facings is "Teflon" TFE-fluorocarbon resin. Faulty valve operation has accounted for as much as 25 percent of all operating complaints at TEL blending plants, duPont claims.

(Continued on Page 95)



NEW PRODUCTS

(Continued From Page 94)

Welding

Arcos Corp., Philadelphia, Pa. has adapted the use of consumable weld inserts to joining the hemispherical halves of a nuclear reactor pressure vessel which handle a highly corrosive process fluid of heavy water under 2000 psi pressure. The inside of the weld had to be smooth, uniform and crevice free. All welding had to be done from the outside.

Zirconium

Mallory-Sharon Metals Corp., Niles, Ohio has printed a 16-page booklet presenting technical and application data on zirconium and hafnium. The metals' high corrosion resistance is one of the characteristics given. Cost data and tips on fabrication are included. Additional information may be obtained from the company.

•

Columbia-Southern Chemical Corp., has adopted zirconium components for critical automatic control valves used in the manufacture of liquid chlorine. An air-operated, diaphragm control valve with a zirconium stem and Teflon chevron packing lasted approximately two years without failure. Previously, valves used in this service with stainless steel stems lasted from one to six months. Further information may be obtained by writing Columbia-National Corp., 70 Memorial Drive, Cambridge 42, Mass.

MEN in the NEWS

Charles C. Nathan and **Marcene S. Goldman,** research chemists at Texaco's Bellaire laboratories, are co-patentees of a method of prevention of paraffin deposition and plugging. Mr. Nathan is a member of NACE, and is active in the organization.

•

Edward R. Krueger has been appointed technical sales representative for the metalworking chemicals division of the American Chemical Paint Co., Ambler, Pa. He will work in Wisconsin, upper Michigan peninsula and northern Illinois.

•

The International Nickel Co., Inc., New York, N. Y., has promoted one man and assigned two others to research positions in the organization. **John F. Mason, Jr.** has been promoted to handle development activities in the petroleum industry for the development and research division. Mr. Mason succeeds **B. B. Morton** who will be full time supervisor of Far Eastern and Latin American developments. **Vladimir Hospadaruk** has joined the staff of the research laboratory as a research chemist in the electrochemical section. He will work to improve the process of bright nickel electroplating. **Ludwig Anselmini** has joined the staff of the stainless steel and heat resistant alloys section of the development and research division. He will specialize in the field of corrosion and heat-resistant alloy castings.

Three men have been promoted to sales positions with Kelite Corp., Berkeley Heights, N. J. **Robert G. Hazel,** a member of NACE, is now district sales manager, in charge of the Beaumont, Texas district. **Vincent E. Bowes** was made Midwestern Regional sales manager in charge of sales in 12 states. **George S. Johnson** was promoted to district sales manager in the Indianapolis district. The Kelite Corp. manufactures industrial chemicals and steam cleaning equipment.

•

A. W. Haydon has organized a new business known as Haydon Instrument Co., Waterbury, Conn. The firm will design and manufacture devices such as high speed numeral counters and printed circuit motors and will provide help with instrumentation and electromechanical problems.

•

George W. Seagren has been named director of research by Stoner-Mudge Co., Pittsburgh, Pa. Mr. Seagren has written articles on corrosion and its prevention for CORROSION magazine and other numerous scientific journals and reference texts. He formerly was head of a multiple fellowship sponsored by Stoner-Mudge at the Mellon Institute of Industrial Research. He is a member of National Association of Corrosion Engineers, the American Association for the Advancement of Science, American Chemical Society, New York Academy of Science, Institute of Food Technologists and other societies. Stoner-Mudge is a division of American-Marietta Co. The firm makes protective coatings for the container, paper, appliance, textile, metalworking, plastics and automotive industries.

•

O. W. Wade is president of a new firm, World Supply Co., 3400 Montrose Blvd., Houston, Texas. The company provides corrosion engineering services for the petroleum and pipe line industries. Mr. Wade is a member of NACE, is active in short course, technical committee and other national and regional activities of the association. He also served as chairman of the American Gas Association's corrosion committee and formerly was chief corrosion engineer for Transcontinental Gas Pipe Line Corp. **Pearce R. Butterfield,** formerly corrosion engineer for Transcontinental Gas Pipe Line Corp., has joined the new organization as sales engineer. He is a member of NACE.

•

G. H. Draper has been appointed Texas sales representative of St. Louis Steel Casting, Inc. The firm makes quality controlled steel castings, many of which are used in the oil industry.

•

Badger Mfg. Co., Cambridge, Mass. has newly elected directors, James S. Carey and Philip H. Seaver. Mr. Carey has been manager of Badger's New York sales office since 1952. Mr. Seaver has been a sales engineer with the company since 1951. Elected to a vice-president's post was **Anson W. Krickl** who will continue as manager of the manufacturing division.

•

Maurice H. Bigelow has been made vice-president of Barrett Division, Al-

(Continued on Page 96)

POSITIONS WANTED and AVAILABLE

- Active and Junior NACE members and companies seeking salaried employees may run without charge two consecutive advertisements annually under this heading, not over 35 words set in 8 point text type.
- Advertisements to other specifications will be charged for at $10 a column inch.

Positions Wanted

Englishman, 3 years' experience in marine, industrial and underground cathodic protection field, office supervising, sales and consultancy. Age 30. Married. Will accept Canada, USA or Europe. CORROSION, Box 58-7.

Five and one-half years' experience in cathodic protection and corrosion engineering work. Desire location in Southwest. Would consider foreign location. Reply to CORROSION, Box 58-6.

Corrosion Engineer—graduate ChE with 5 years' corrosion engineering and 7 years' chemical process engineering experience in organic and inorganic chemical manufacturing. Will set up corrosion control program incl. testing, evaluation, specifications and standards. Willing to relocate. CORROSION, Box 58-8.

Six years' experience applied and basic research on metals corrosion. Group leader. Technical papers. Strong training metal selection, non-ferrous extractive metallurgy, hydrometallurgy, X-ray diffraction, spectroscopy and chemical analysis. PhD in Met. E. Age 39, married. CORROSION Box 58-10.

Distributorship Wanted

Distributorship Wanted. Operating protective coatings distributor on Texas and Louisiana Gulf Coast, with good Dun & Bradstreet, desires additional line of coatings or allied product. Reply to CORROSION, Box 58-9.

Positions Available

Wanted! Corrosion engineer with paint experience to sell corrosion barrier coatings and industrial paints in Southern Louisiana and Gulf Coast territory from Houston to New Orleans. Address correspondence to Ainslie Perrault, President, Allied Paint Mfg. Company, P. O. Box 1088, Tulsa, Oklahoma.

UNUSUAL OPPORTUNITY

for sales engineer to become part of a company which is recognized as a leader in the field of protective coatings.

We need a man with oustanding sales ability. Earnings and opportunity on executive level.

A brief outline of your qualifications would provide basis for further confidential correspondence. Our own sales personnel know of this ad.

Write CORROSION, Box 58-11.

J. M. PEARSON

•

Contributions of J. M. Pearson to Mitigation of Underground Corrosion

Six articles by the late Dr. J. M. Pearson and one by an associate prepared under his leadership are reprinted for the information of new workers and established investigators into underground corrosion problems. Dr. Pearson, recipient of the 1948 NACE Speller Award for achievements in corrosion engineering, is recognized for his outstanding work on problems associated with corrosion of metals underground. The articles, originally published during 1941-44 in The Petroleum Engineer and in Transactions of The Electrochemical Society are reprinted by permission in this book dedicated to him.

•

Papers included are:
Electrical Examination of Coatings on Buried Pipelines
"Null" Methods Applied to Corrosion Measurement
Determination of the Current Required For Cathodic Protection
Concepts and Methods of Cathodic Protection, Parts I, II and III
Preventive Maintenance by Systematic Pipeline Inspection by Donald F. Van de Water

•

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MEN in the NEWS

(Continued From Page 95)

lied Chemical Corp. He will continue as head of Barrett's research and development department.

•

Norman J. Johnson has been appointed manager of operations for A. M. Byers Co.

•

W. Samuel Carpenter III became assistant general manager of the E. I. duPont de Nemours & Co., Inc. Electrochemicals Department on May 1.

•

Frank W. Hightower now heads the ultrasonic cleaning and processing division of Engineering Test Services, Inc. Tulsa.

•

W. Wallace Anderson has been named plant manager of the Tretolite Company of California Division of Petrolite Corp. at Los Angeles, succeeding **C. N. Stehr,** now on special assignment for the corporation.

•

Wouter Bosch has been appointed professor of chemistry at the University of Missouri, School of Mines and Metallurgy, Rolla. He has designed as chairman of the Department of Paints, Varnishes and Lacquers at North Dakota Agricultural College, Fargo.

•

Arthur B. Guise, technical director of Ansul Chemical Co. has been appointed to the Fire Research Conference, a body of the National Academy of Sciences in Washington.

•

William W. Tobin is a new technical sales representative for Geigy Industrial Chemicals in the metropolitan New York and Connecticut areas.

•

J. E. Burrell has been appointed general manager of operations for Columbia-Southern Chemical Corp.

•

Donald L. Garrison has been transferred to Chicago as District Manager—Gas for Dresser Manufacturing Division. The division also announced that **James L. Mattern** has been transferred to Atlanta, Ga. as Southeastern District Manager—Gas and **Richard T. Alt** has been appointed North Central District Manager—Gas with headquarters in Minneapolis.

•

Bradford H. Arthur has been appointed assistant to the president of Prufcoat Laboratories, Inc.

•

Ben R. Medford, Jr. is now a field sales engineer for the F. H. Maloney Co., Houston, operating out of Maloney's Tulsa office. He has been replaced in the Houston office by **Lee Dawson.**

•

Alfred T. Daech has been named group leader in the Research and Development Laboratory of Carbonline Company, St. Louis.

•

Warren K. Brown is new chief engineer of Chemical Linings, Inc., 156 Stone St., Watertown, N. Y. **Alan T. Campbell** has been appointed assistant to the president.

Miro A. Grottger has joined Industrial Finishes Co., 1119 Land Title Bldg., Philadelphia 10, Pa. as vice-president and director of research.

•

Frederick J. Close has been named general manager of the sales development and commercial research division of Aluminum Company of America.

•

Joseph J. Duffy, Jr. has joined the staff of Kain & Hooven, consulting engineers, Landowne, Pa. He formerly was manager of Pennsalt Chemical Corp. Metal Processing Dept.

•

Ludwig Anselmi will specialize in corrosion and heat resistant alloy castings as a member of the staff of the Stainless Steel and Heat Resistant Alloys Section of the Development and Research Division of the International Nickel Co., Inc.

•

Roy D. Super has been appointed industrial sales representative for Napko Paint Corp., Houston.

•

John H. Gibbs is field engineer for Beckman Systems Division. Mr. Gibbs will have headquarters in Houston, and will serve customers in the Southwestern states.

•

Q. T. Wiles, president of Good-All Electric Mfg. Co., Ogallala, Neb. has been elected to membership in the Young Presidents organization. The society is open to presidents of firms having at least $1,000,000 annual gross revenue with fifty employes. Members must have become presidents before the age of 40. Mr. Wiles came to Good-All from Shell Development Co., Emeryville, Cal., in 1951.

•

Rudolph A. Schatzel, vice president and research director of Rome Cable Corp., Rome, N. Y. outlined the importance of synthetic rubber to the electrical wire and cable industry at a special panel discussion of the Commercial Chemical Development Association's annual meeting in New York City on March 27. He is a past president of the American Society of Testing Materials.

•

Frank Bright has been appointed sales manager of Standard Magnesium Corp., Tulsa.

•

John W. Bradley, The Bunker Hill Co. has been named president and chairman of the board of directors of the Lead Industries Association.

•

E. H. Garnett is manager of the newly opened Kansas City office of Shutt Process Equipment Corp., 6317 Raytown, Rd.

•

Stuart S. Carlton has been appointed director of sales for Horizons Inc., Cleveland.

•

Irving P. Schwerd has become chief engineer of the Belleville, N. J., manufacturing plant of L. Sonneborn Sons, Inc.

•

P. B. Mayfield, Barrett Division, Allied Chemical Corp. has been elected president of the American Wood Preserver's Association.

New Map Records Improve Efficiency of Corrosion Control on Pipe Lines*

Abstract

Savings that can be realized in maintaining special records on the histories of underground pipe lines and transmission systems are pointed out. A list is given of the various maps that can help in protecting a piping system and some comments are made on the manner in which corrosion control work should be administered and organized. 5.2.1

TWO PRINCIPAL changes are coming about in the practice of cathodic protection on underground pipelines of gas distribution and transmission companies. The first of these is recognition of the importance of compiling and keeping special records on underground plant; the second is the change in duties of the cathodic protection crew to those principally associated with investigation and inspection.

Concurrently also is a gradual shifting in the duty of actually installing cathodic protection to the maintenance and rebuild crew. This has the effect of making the foreman responsible for cathodic protection, a very important change, insofar as the cathodic protection engineer is concerned.

The principal records are a series of maps and overlays which result from accumulated records and also from certain surveys, some of which are new.

Elements of Mapping

The principal elements of the new map records are:

The Leak Map. This map is compiled from a "leak repair report," made by personnel who actually repair the leak. The data should be posted on the map and the report filed. This map should be permanent and available to all personnel.

Information not normally included in a leak report should also be entered here. For instance, budget item replacements with job order numbers. An effort should be made also to post pertinent items not covered by leak repair reports.

Bar Test Maps. Affirmative tests should be marked as, for example: A—Requires immediate repair, either because of size or location. B—Requires routine repair. C—Borderline, may be watched another year. Another way of grading would be to consider the leaks as, in order,

A—Will burn at the top of the bar hole; B—100 percent explosive on the explosimeter and might flash if lit; and C—Up to 100 percent on the explosimeter.

Age Maps. The age of each line should be shown. Besides other obvious uses, these maps help in the study of possible replacements.

Coating Maps. It is important to know which lines are coated and which are not. Often a decision on whether to replace or use cathodic protection may hinge on whether or not the line is coated and how old it is. If high resistance is noted in coating tests, for example, it is an indication the pipe may be in good condition.

Soil Resistivity Maps. Bar testing crews can take soil resistivity measurements at a modest cost in connection with their work. This map, when overlaid with leakage data is very significant. These data also help in planning replacements and in indicating areas where intensive explosimeter testing should be done.

Organization of Work

A system with excessive leakage means overloaded maintenance crews under old procedures. By initiating the above data collection program, maintenance crew work, which will include cathodic protection, can be made more efficient and less of a stop-gap nature, with the result that the work load gradually eases. Executives find job orders contain statements that the necessity for the work has been checked against soil resistivity surveys. Other data, such as identification of bare pipe, also appear. This provides managers with much more factual data on which to base decisions.

The current trend is to use area gangs for work either on transmission or distribution. The office of the area superintendent will keep the local records and his staff will collect the data.

The cathodic protection man, who once called finding three or four accidental contacts a good day's work now finds himself being made responsible for the condition of his company's major investment. With this responsibility comes the authority to do the job. As far as utility supervisors are concerned, young ones directing maintenance will need to know cathodic protection and the older ones will have to learn it.

★ Extracted from "Integration of Leakage Surveys and Cathodic Protection in Gas Distribution Systems," by James R. Cowles, consultant, Tulsa. A paper presented at a meeting of South Central Region, National Association of Corrosion Engineers, Oklahoma City, October 1-4, 1957.

TECHNICAL REPORTS on CORROSION in UTILITIES

T-4B Cell Corrosion on Lead Cable Sheaths. Third Interim Report of Technical Unit Committee T-4B on Corrosion of Cable Sheaths. Compiled by Task Group T-4B-1 on Corrosion of Lead and Other Metallic Sheaths. Publication No. 56-9. Per Copy $.50.

T-4B-2 Cathodic Protection of Cable Sheaths. Fourth Interim Report of Technical Unit Committee T-4B on Corrosion of Cable Sheaths. Compiled by Task Group T-4B-2 on Cathodic Protection. Publication 56-13. Per Copy $1.00.

T-4B-3 Tests and Surveys for Lead Sheathed Cables in the Utilities Industry. Second Interim Report of Technical Unit Committee T-4B on Corrosion of Cable Sheaths. Publication 54-6. Per Copy $.50.

T-4B-4 Pipe-Type Cable Corrosion Protection Practices in the Utilities Industry. First Interim Report of Technical Unit Committee T-4B on Corrosion of Cable Sheaths, *Corrosion*, Sept. 54 issue. Publication 54-3. Per Copy $1.00.

T-4B-6 Stray Current Electrolysis. Fifth Interim Report of Technical Unit Committee T-4B on Corrosion of Cable Sheaths, prepared by Task Group T-4B-6 on Stray Current Electrolysis. Publication No. 57-1. Per Copy $1.00.

T-4F-1 Progress Report of Task Group T-4F-1 on Water Meter Corrosion. Per Copy $.50.

TP-12 Report on Electrical Grounding Practices. Per Copy $.50.

TP-19 Corrosive Effects of Deicing Salts—A Progress Report by Technical Practices Committee 19. *Corrosion*, January, 1954, issue. NACE members $.50; Non-members $1 per copy.

Remittances must accompany all orders for literature the aggregate cost of which is less than $5. Orders of value greater than $5 will be invoiced if requested. Send orders to National Association of Corrosion Engineers, 1061 M & M Bldg., Houston, Texas. Add 65c per package to the prices given above for Book Post Registry to all addresses outside the United States, Canada and Mexico.

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Some Physical and Chemical Properties of Aromatic Polycarbonate Resins by K. B. Goldblum, General Electric Co., Pittsfield, Mass.

How to Make a "Corrosion Motor" by Reuben Tullis, San Diego, Cal.

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CORROSION ABSTRACTS

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1. GENERAL

1.6 Books

1.6, 3.2.2, 3.1

Progress in Metal Physics. Vol. 6. B. CHALMERS AND R. KING, Editors. Book, 1956, 354 pp. Pergamon Press Ltd., London & New York.

Monographs by different authors, with name and subject indices.

A. W. Lawson, The Effect of Hydrostatic Pressure on the Electrical Resistivity of Metals, H. K. Hardy; The Filamentary Growth of Metals. A survey on the growth of metal whiskers on minerals and sulphides, on and from halides, on metals, by electrodeposition, replacement, condensation and unknown causes; non-metallic growths on metals; crystal structures and electrochemical characteristics; mechanism of whisker formation. 108 references); R. F. Mehl and W. C. Hagel, The Austenite: Pearlite Reaction; A. H. Sully, Recent Advances in Knowledge Concerning the Process of Creep in Metals; O. Knacke and I. N. Stranski, The Mechanism of Evaporation; P. H. Hirsch, Mosaic Structure.—BNF. 13547

1.6, 3.8.4, 3.2.3, 3.5.9

Oxidation of Metals and Alloys. (In German.) KARL HAUFFE. Book, 1956, 389 pp. Published by Springer-Verlag, Reichpietschufer 20, Berlin W. 35.

The models of point defects in ionic crystals and semi-conductors are the basis on which the mechanisms of logarithmic, inverse logarithmic, cubic and parabolic oxidation are being quantitatively, authoritatively and exhaustively discussed. In addition, there are sections on catastrophic oxidation, the attack of sulfur and sulfur compounds on metals, the oxidation of "hard metals," the mechanism of oxidation in aqueous electrolytes and a brief one on experimental methods.

The 26 pages of diffusion data in metals might have been omitted but the table on diffusion in inorganic compounds is a useful summary.

Of particular interest to those who deal with the application of scientific principles to practical ends should be the frequent attempts of Hauffe to explain empirical results, at least qualitatively by means of the known mechanisms and to make suggestions about the most promising lines to be followed for practical improvements. In places, however, one might ask for the inclusion of brief summaries indicating clearly the qualitative implications of the quantitative considerations.

The book should be particularly useful to anyone engaged in laboratory work who is interested in, and moderately familiar with, the fundamental background of oxidation theory.—MA. 13955

1.6, 3.5.8, 3.8.4, 2.3.7

Brittle Behavior of Engineering Structures. E. R. PARKER. Book, 1957, 323 pp. John Wiley & Sons, 440 Fourth Avenue, New York.

Summarizes available information on brittle behavior in engineering structures and contains a discussion of theories and mechanism of failure, a review of test methods used for evaluating relative brittleness, interpretations and summaries of test results and a report of service failures.—INCO. 14186

1.6, 3.8.4, 3.5.9, 6.1

Heat- and Corrosion-Resistant Materials: Plansee Proceedings, 1955. Parts I, II. F. BENESOVSKY, Editor. Book, 1956, Pt. I, 1-40; Pt. II, 41-215. Published by Metallwerk Plansee G.m.b.H., Reutte, Tyrol, Austria.

Part I. Diffusion in Some Oxide Systems, J. A. Hedvall (in German); The Adsorptive Affinity of Hard Materials and Their Relation to Hardness and to Their Chemical Stability, G. F. Huttig and E. Hartl (in German); The Oxidation Mechanism of Metals and Alloys at High Temperatures, O. Kubaschewski (in German); The Microplasticity of Hard Materials, A. G. Smekal (in German).

Part II. Investigation of the Structure of Hard Alloys with the Electron Microscope, R. Bernard (in French); Properties of Arc-Melted vs. Powder Metallurgy Titanium Carbide, I. Cadoff, J. P. Nielsen and E. Miller; $MoSi_2$ as a High Temperature Material, E. Fitzer (in German); Interactions in Mixtures of Hard Materials at Very High Temperatures, G. A. Geach and F. O. Jones; Some Properties of a Recently Developed Hard Metal Produced by Infiltration, C. G. Goetzel and L. P. Skolnick; The Role of the Binder Phase in Cemented Carbides, J. Gurland and J. T. Norton; Titanium Carbide Base Cermets, W. L. Havekotte; The Oxidation of Mixed Cemented Carbides for High Temperature Purposes, J. Hinnuber, O. Rudiger and W. Kinna (in German); The Niobium-Silicon and Vanadium-Silicon Systems, R. Kieffer, H. Schmid and F. Benesovsky (in German); The Structure of Silicides, H. Nowotny, H. Kudielka and E. Parthe (in German); Borides of Rare Earth and Related Metals, B. Post, D. Moskowitz and F. W. Glaser; The Stability of Some Metal Silicides of Potential Value in High Temperature Materials, D. A. Robins and I. Jenkins; The Sintered High Temperature Materials, P. Schwarzkopf (in German); Contribution to the Study of the Ternary System CTi-CZr-CW, F. Tombrel (in French).—BNF. 13937

1.6, 3.5.9, 6.1

Heat- and Corrosion-Resistant Materials: Plansee Proceedings, 1955. Parts III, IV. F. BENESOVSKY, Editor. Book, 1956, Pt. III, 216-334; Pt. IV, 335-472. Published by Metallwerk Plansee G.m.b.H., Reutte, Tyrol, Austria.

Part III. Sintered Materials for High Vacuum Technology, M. Auwarter (in

Abstracts in This Section are selected from among those supplied to subscribers to the NACE Abstract Punch Card Service. Persons who are interested in reviewing all available abstracts should write to NACE for information on this service.

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LIBRARY OF CONGRESS, Washington, D. C.

JOHN CRERAR LIBRARY, 86 East Randolph St., Chicago 1, Ill.

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German); Investigations of the Structures of Tungsten-Chromium- and Molybdenum-Chromium-Rich Alloys of the Tungsten-Chromium-Nickel and Molybdenum-Chromium-Iron Systems, H. Buckle (in German); The Thermal Chromising of Molybdenum-Rich Sintered Alloys, H. Buckle (in German); The Alloys of Rhenium with Molybdenum or with Tungsten and Having Good High Temperature Properties, G. A. Geach and J. E. Hughes; The Solubility of Oxygen in Tantalum and the Related Changes in Properties, E. Gebhardt and H. Preisendanz (in German); Some Aspects of the Technology of Molybdenum and Its Alloys, J. Harwood; The Role of Powder Metallurgy in the Design of Nuclear Power Reactors, H. H. Hausner and M. C. Kells; Experiments with Models on the Formation of the Staple Wire Structures ("Stapeldrahtgefüge") in Tungsten, J. L. Meijering (in German); The Recrystallisation Mechanism of Molybdenum and Tungsten, E. Nachtigall (in German); Sintered Cobalt-Based Alloy for Gas Turbine Blading, E. R. Perry and I. Jenkins.

Part IV. Silver Alumina Bodies, T. H. Blakeley and A. E. S. White; High Temperature Materials and Methods of Evaluation, W. B. Crandall and J. R. Tinklepaugh; Decarburization of Thoriated Tungsten Filaments for Use in Vacuum Tubes, Y. Ishikawa and K. Hayashi; The Wetting Properties of Solid Oxides and Carbides by Liquid Metals, D. T. Livey and P. Murray; Increasing the Heat Resistance by Inner Oxidation of Alloys, J. L. Meijering (in German); Metallic Sintered Materials with Synthetic Integranular Substances, R. Mitsche (in German); The Sintering Behaviour, Microstructure and Properties of Chromium-Aluminum Oxide-Cermets, E. M. Onitsch-Modl (in German); A Technical Sintering Diagram, G. Ritzau (in German); Powder Ceramics—Powder Metallurgy: A Review of Relationship and Developments, M. A. Schwartz; New Investigations in the Field of Sintered Aluminum Powder, S.A.P., A. Von Zeerleder, R. Irmann and F. Leichti (in German).—BNF. 13938

1.6, 7.7, 5.2.3

Selection and Application of Metallic Rectifiers. STUART P. JACKSON. Book 1957, 326 pp. The McGraw-Hill Book Co., Inc., 330 West 42nd St., New York 36, New York.

The book is designed to present reference information useful in application of metallic rectifiers. Sections are devoted to application; circuits, complex loads and filters; selection of correct type, copper-oxide, selenium, magnesium-copper, germanium and silicon rectifiers; condensed theory of junction rectifiers, application of theories to rectifiers; battery charging; electroplating supplies; industrial power supplies; application; magnetic amplifiers; special purpose circuits and definitions.

The book is profusely illustrated with diagrammed data, contains numerous tables and formulas, bibliography and index. 14673

1.7 Organized Studies

1.7.2, 2.2.2

Key West Corrosion Test Site Reclassified. *ASTM Bulletin,* No. 215, 58 (1956) July.

The table gives corrosion rates for large numbers of materials at three ASTM corrosion sites. The examination of these results has led to a change in the classification of the Key West site from "marine" to "rural (marine)." This is intended to indicate a mild atmosphere, free from industrial pollution, but slightly contaminated by sea spray. —ZDA. 13486

1.7.1

Chemistry Research 1956. 1957, 86 pp. Report of Chemistry Research Board with the Report of the Director of the Chemical Research Laboratory, Dept. of Scientific and Industrial Research, London. Available from: British Information Services, 45 Rockefeller Plaza, New York 20, N. Y.

A wide variety of information on the work of British governmental agencies concerned. Principal interest for corrosion workers is in sections relating to metals corrosion where activities in connection with metals underground and exposed to various atmospheric and chemical environments are reported.

Details of other research work are given in general terms, including some information on high temperature oxidation, purification of elements and air pollution. Interesting information is given on the National Colletcion of Industrial Bacteria, which seeks to catalog nonmedical bacteria of industrial importance. Studies on sulfate-reducing bacteria are described including means used to control their growth.

A list of publications and patents is included. 14703

1.7.3, 8.9.3

The Corrosion Engineer and His Contribution to an Economic Underground Pipeline Project. A. GROSS. *Corrosion Prevention & Control,* **4,** No. 2, 37-43 (1957) Feb.

Discusses responsibilities of corrosion engineer with respect to selection of proper cathodic protection scheme, selection and treatment of coatings, installation of pipeline, field survey for stray currents, consideration of geological conditions, current drainage tests, and post-installation survey.—INCO. 13793

2. TESTING

2.1 General

2.1.1

Logarithmic Transformations in the Analysis of Corrosion Data. H. C. BOWEN, C. GROOT AND J. L. JAECH. Hanford Atomic Products Operation. U. S. Atomic Energy Commission Pubn., HW-48753, February, 1957, 10 pp.—BTR. 14232

2.1.2, 2.2.2, 5.4.5

Testing Paints by Outdoor Exposure. II. Assessment of Film Deterioration. C. R. EDWARDS AND E. JENKINS. *Paint Manuf.,* **26,** No. 11, 411-416 (1956) Nov.

The first part of the article appeared in the October issue and described the Ministry of Supply test site at Glascoed in Monmouthshire. The second part is concerned with assessing the panels for gloss, dirt retention, chalking, checking, etc. and recording the ratings. The figures show various types of failure.—ZDA. 13984

2.1.2, 2.2.1, 2.3.1

Artificial Aging in Test Chambers Versus Natural Aging in the Field and in Extreme Environments. ALFRED N. BLOCH. *Am. Paint J.,* **41,** 98+ 9 pp. (1957) January 14.

Correlation between natural and artificial aging. Present problems and future outlook of accelerated test methods.—BTR. 13520

2.2 On Location Tests

2.2.2, 6.6.11, 5.4.5

Preservation of the Exterior Surfaces of Wooden Shipping Containers to Retain Identification Symbols in Long-Term Outdoor Storage. H. W. EICKNER AND E. A. MRAZ. Rock Island Arsenal for Chief of Ordnance, U. S. Army, May, 1956, 25 pp. Available from Office of Technical Services, U. S. Dept. of Commerce, Washington, D. C. (Order PB 121666).

Stencil markings of red iron oxide (barn) paint retained the best legibility of four materials tested on wooden shipping containers after exposure for one year to various outdoor storage conditions, according to this report of field tests in three different climates. However, undercoat treatment with a water-repellant preservative and topcoat treatment with a clear varnish combined with the other marking materials protected the wood and stencil markings as well as the red iron oxide paint. The marking materials were used on boxes of red oak, southern yellow pine and Douglas fir. 13577

2.2.2, 5.4.5

Experiments on Behavior of Paint with Various Pigments Under Five Different Climatic Conditions. (In German.) H. GERET. *Schweiz. Archiv angew. Wiss. u. Tech.,* **22,** No. 3, 102-104 (1956) March.

Final results of four years' exposure. 13974

2.2.7, 4.6.11

Changes in Sea-Water Characteristics in a Corrosion Testing Station. (In French.) L. BARRIETY, J. DEBYSER AND A. HACHE. *Corrosion et Anticorrosion,* **5,** 51-57 (1957) February.

Effect of photosynthesis on corrosion of steel by sea-water. Effect of sunlight on temperature, pH, dissolved oxygen and other properties of the water. During summer the oxygen content of the seawater running through the testing vats is twice as great as during other months when sunlight is not so intense.—BTR. 14070

2.3 Laboratory Methods and Tests

2.3.1

Oxidation of Metals: Determination of Activation Energies. P. KOFSTAD. *Nature,* **179,** No. 4574, 1362-1363 (1957) June 29.

Description of a new faster method for determination of activation. Metals are oxidized under conditions of linearly increasing temperature and method gives activation energy of oxidation from 1 single oxidation run, and in addition gives the approximate temperature regions in which different rate-laws of oxidation are found. Method described was tested for nickel, zirconium, copper and titanium over temperature range 400-1,050 C and results are given. Graph, table.—INCO. 14324

2.3.1

Application of a Systematic Scheme for Examining Corroded Metal Specimens. J. B. COTTON AND R. J. WATKINS.

Corrosion Technology, **4**, 39+ 5 pp. (1957) February.

Various techniques are applied to examination of a copper hot-water cylinder, aluminum-brass condenser tubes, tin-coated copper specimens, aluminum-bronze plug cock, aluminum alloy wet pulp screen and stainless steel wire mesh.—BTR. 13774

2.3.1, 3.7.3, 6.3.19

Testing and Evaluation of Gas-Welded Joints in Zinc and Zinc-Base Alloys. NIKOLAUS LUDWIG. *Z. Metallkunde*, **47**, No. 7, 473-477 (1956).

Ludwig discusses the following aspects of the testing and evaluation of gas-welded plate joints in zinc and zinc alloys: (1) visual inspection—types of beads associated with satisfactory and unsatisfactory fluxes; (2) mechanical testing—German standard specifications relating to mechanical testing; tabulated data on the mechanical properties of welds in 98.5-99.99% zinc in relation to thickness, width, and type of joint, flux, flame, post welding treatment; typical UTS of welds in zinc-base alloys with aluminum and/or copper; (3) structure of the weld and transition zone; (4) corrosion-resistance to (a) dry air, and water vapor at 95 C, (b) an atmosphere of 80% relative humidity and containing 0.1% sulfur dioxide, (c) a solution containing sodium chloride 3 and hydrogen peroxide 0.1%, and (d) 30% sulfuric acid; (5) the attack of residual traces of various proprietary fluxes on fine zinc after 7 weeks in an atmosphere of 86% relative humidity. 8 references.—MA. 13641

2.3.2

A New Method of Studying the Atmospheric Corrosion of Metals. (In Russian.) T. I. LUKONINA, K. A. ZHIGALOVA AND I. L. ROZENFEL'D. *Factory Lab.* Zavodskaya Laboratoriya), **22**, 1463-1467 (1956) Dec.

An arrangement for producing an atmosphere of given composition with specific moisture content by passing the air through moistened salts.—BTR. 13614

2.3.2, 2.4.3, 5.3.2

The Misuse of the Preece Test. B. J. BARMACK. *ASTM Bull.*, No. 217, 38 (1956) October.

The difference in solution rates of pure zinc (electrogalvanized coatings) and zinc/zinc-iron layers (hot-dip galvanized coatings) is pointed out and it is concluded that the Preece test may show more favorable results for hot-dipped compared with electrogalvanized coatings that are not a true reflection of the protective value when the test is compared with outdoor exposure results. Non-destructive magnetic tests are recommended for determining average coating thickness and distribution of zinc.—BNF. 13483

2.3.2, 5.3.2

Third Progress Report on Accelerated Corrosion Tests for the Performance of Plated Coatings. W. L. PINNER. *Tech. Proc. Am. Electroplaters' Soc.*, **1956**, 50-55, 290-291.

There are discussions of the acetic acid modification of the salt spray test (ASTM Method B287-54T) and of the Corrodekote test (rubbing the cleaned finished part with mixture of kaolin and a suitable chemical mixture to promote corrosion, reproducing action of slush from snow treated with salt; useful results have been obtained from a mixture containing cupric nitrate, ferric chloride, ammonium chloride, kaolin and water). —BNF. 13669

2.3.2, 5.4.5

Blistering. H. W. CHATFIELD. *Paint-india*, **6**, No. 2, 11-12 (1956).

Blistering appears to be more severe in finishing system coated on non-absorbent metal panels, in weatheromometer, than during outdoor exposure in temperate climates, though correlation may be better with semi-tropical or tropical exposure. The phenomenon usually appears, if it is to occur at all, within the first few days of testing and may later disappear. If weatherometer exposure is to be used as a standard test for blistering tendency, certain precautions are essential; these include absence of pits or rust pockets and deep scoring on steel panels, absence of contaminants on the surface generally, e.g., steel dust on aluminum surfaces from use of abrasive paper previously used on steel and accurate control of film thickness. Blistering at the metal surface should be distinguished from intercoat blistering.—RPI. 13565

2.3.2, 5.3.2

Accelerated Corrosion Tests for the Performance of Plated Coatings: Fourth Progress Report. W. L. PINNER. Hou-

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81a

daille Inds., Inc. *Plating*, **44**, No. 7, 763-766 (1957) July.

This report of Am. Electroplaters' Soc. Research Project No. 15 presents tentative procedures for the conduct of 2 accelerated methods for testing outdoor durability of chromium plated steel and zinc alloys. These are the Acetic Acid Salt Spray test as prepared by General Motors Corp. and the Corrodkote Test as prepared by Chrysler Corp. —INCO. 14780

2.3.2, 5.5.3

Controlled Moisture Condensation Apparatus for Evaluation of Rust-Preventive Oils. H. RODEN. *ASTM Bull.*, No. 223, 55-61 (1957) July.

Box-type humidity cabinet tests are included in government specifications and such cabinets are widely used by commercial laboratories for evaluation of several types of rust preventive compounds and preservative lubricating oils. Such tests are used to measure protectiveness of oils and compounds after application to flat steel specimens which are then subjected to high humidity and moisture condensation at 100-120 F for specified periods of time or until rusting occurs. Unsatisfactory features of box-type cabinet are low reproducibility and excessive testing time, especially for commercial products which require preshipment test and approval. Comparative tests with a closed-cell high humidity, moisture condensation apparatus which provides specific temperature differences between humid ambient air and steel surface, were a faster, more reproducible method. Photos, diagrams, tables. —INCO. 14863

2.3.2, 5.3.2

The Standard Salt-Spray Test: Is It A Valid Acceptance Test? A. MENDIZZA. Paper before Am. Soc. Testing Materials, Symp. on Properties, Tests, and Performance of Electrodeposited Metallic Coatings, Spr. Mtg., Buffalo, Feb. 29, 1956, and 2nd Pacific Area Nat'l Mtg., Los Angeles, Sept. 19, 1956. ASTM Special Technical Pubn. No. 197, 1957, 107-117; disc., 118-129; *Plating*, **44**, No. 2, 166-171; disc., 171-175 (1957) Feb.

Presents graphically the data obtained from ASTM investigation to determine relationship between salt-spray resistance and coating thickness, and to determine degree of reproducibility of test data for coatings prepared to same thickness requirements by several producers and tested by several laboratories in accordance with ASTM Method B-117. Data are evaluated with respect to objectives of investigation and some data are analyzed statistically. Test panels were plated with nickel (0.0015, 0.00125 and 0.00075 in. deposits) and copper plus nickel. Rust spot checks were made every 24 hours. Statistical analysis showed that test boxes and platers were not consistent, and that measurements of large and small rust spots are not statistically independent. It is concluded that salt-spray test as currently practiced fails to perform as a standard test. Charts.—INCO. 13783

2.3.4, 5.4.5

Evaluating Chemical Resistance of Coatings. J. I. RICHARDSON. *Org. Finishing*, **18**, No. 3, 14-15 (1957).

An evaluation procedure suggested comprises application of the test paints to 6" x 1" diameter steel rods with rounded ends followed by immersion in a number of acid, alkali and salt solutions, water and organic solvents.—RPI. 14344

2.3.4

Analysis of Corrosion Products by Paper Chromatography. D. G. STERN AND F. CORRY. *Metal Treatment & Drop Forging*, **24**, No. 138, 93-97 (1957) Mar.

Reviews the history and principles of chromatographic methods of analysis, with special emphasis on procedure and typical results for partition chromatography. Selection of type of support and solvent is discussed. Physical methods for locating and identifying zones include use of radioactive tracers, spectrographic analysis, colorimetric means and others. For chemical identification, table summarizes reagents and elements identified by them. Sketch shows typical separation of nickel, cobalt, copper and iron with methyl-ethyl ketone/water/hydrochloric acid solvent mixture, after spraying with rubeanic acid and exposing to ammonia. Technique was applied to investigation of corrosion products in electrical switch-gear and on light alloy and steel housing.—INCO. 14137

2.3.4, 5.8.1

New Method of Studying Corrosion Inhibition of Iron with Sodium Silicate. E. F. DUFFEK AND D. S. MCKINNEY. *J. Electrochem. Soc.*, **103**, No. 12, 645-647 (1956) Dec.

A rapid laboratory method is presented for testing the effectiveness of sodium silicate as an anodic inhibitor. Passivity curves taken on polished steel electrodes, pretreated for 24, or better, 48 hr. in aerated solutions of sodium silicate (3-500 ppm silica) and compared with sodium hydroxide solutions of the same pH, indicate that silica and not merely an increase in pH, caused inhibition. No corrosion products were observed in the short pretreatment time for electrodes treated with 15 and more ppm silica, whereas all sodium hydroxide treated electrodes corroded. The method can be made the basis of a practical test by pretreating the electrodes, in the actual environment being treated, with sodium silicate. The procedure also appears to be applicable in the testing of other anodic inhibitors. 13874

2.3.4, 5.8.1, 2.3.8, 4.6.4

Evaluation of Laboratory Testing Techniques for Cooling Water Corrosion Inhibitors. NACE Task Group T-5C-1 on Corrosion by Cooling Waters (C. P. DILLON, Chairman); A Report of the Test and Inspection Work Group (L. M. ROGERS, Chairman). *Corrosion*, **13**, No. 5, 345t-346t (1957) May.

Four laboratory corrosion inhibitor testing techniques were employed to determine the best method of testing and to set up specifications for carrying out these tests. The conclusions were that the dynamic flow test is the only one which gives accurate screening of inhibitors for use in recirculated systems. The static test can be applied to storage of water. It was also concluded that an inhibitor must be run in a pilot plant for quantitative data on inhibition of corrosion, scaling, pitting, tuberculation and effect on heat transfer. Specifications for carrying out laboratory and pilot plant tests have been set up and some recommendations for plant procedure are made. 13847

2.3.4

A Hydrogen Effusion Method for the Determination of Corrosion Rates in Aqueous Systems at Elevated Temperature and Pressure. M. C. BLOOM AND M. KRULFELD. *J. Electrochem. Soc.*, **104**, No. 5, 264-269 (1957) May.

This paper analyses the limitations of weight change techniques at elevated temperature and pressure and presents a description of a new technique based on the measurement of the hydrogen generated by the corrosion reaction. This hydrogen which diffuses through the walls of a test specimen containing the aqueous solution, is collected and measured in a vacuum system of known volume which surrounds the test specimen; the corrosion rate is calculated from the hydrogen effusion rate. Results obtained with the technique show good reproducibility and compare well with results obtained by an independent method. See Corrosion Studies in High Temperature Water by M. C. Bloom, M. Krulfeld, W. A. Fraser and P. N. Vlannes, *Corrosion*, **13**, No. 5, 297t-302t (1957) May.

2.3.4

Corrosion Investigation by Means of Aerosols. (In Dutch.) W. HESS-BIRCHER. *Metalen*, **11**, No. 11, 239-245 (1956) June 15.

Physical basis of method. Practical tests.—BTR. 12444

2.3.5, 5.4.5

Application of Impedance Measurements to Corrosion Phenomena. D. M. BRASHER AND F. WORMWELL. *Nature*, **178**, No. 4529, 382 (1956).

A letter drawing attention to the value of resistance and capacity measurements in studying the breakdown of paint films. —RPI. 13540

2.3.5

Determination of Current Density/Voltage Curves with Electronic Potentiometer in Respect to Electrolytic Separation. (In German.) W. KOCH AND H. LUEDERING. *Arch Eisenhuettenw.*, **28**, No. 4, 201-206 (1957) April.

With the potentiometer described it is possible to avoid potential drops and continuous transition from cathodic to anodic load of electrode. Current density/voltage curves of mild steel in electrolyte containing 5 percent sodium citrate and of ferritic 18 percent chromium steel in various electrolytes are given.—BL. 14706

2.3.5, 5.4.5, 4.5.1

Control of Bituminous Coverings of Pipe Destined for Underground Installation. (In Italian.) F. BALDI. *Metallurgia Italiana*, **49**, 337-340 (1957) May.

Details of conductometric test adopted at *Centro Ricerche e Controlli Falck;* actual service conditions of pipe are duplicated in tests to determine covering requirements to prevent corrosion, especially that resulting from stray electric currents. Test method has application in production process. 33 references.—MR. 14542

4. CORROSIVE ENVIRONMENTS

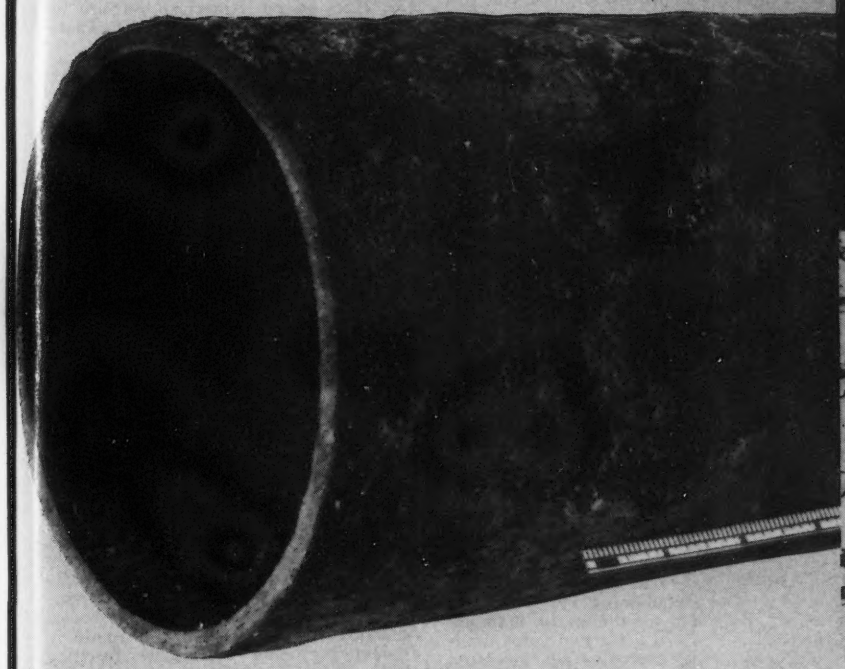
4.3 Chemicals Inorganic

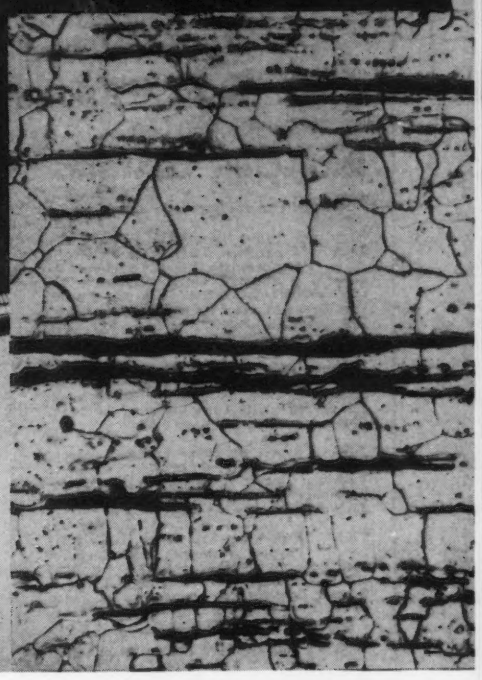
4.3.1, 5.8.2, 6.2.5, 8.4.5

Corrosion Studies on 25-12 and 18-8 Stainless Steel. E. H. TURK. Hanford Works. U. S. Atomic Energy Comm. Pubn., HW-3-2898, Memorandum Rept.

Another Wrought Iron case against corrosion

56
YEARS OF SERVICE





Photomicrograph U-85-3 shows a typical area of the microstructure observed in the subject 5-inch wrought iron pipe.

Metallurgical Report 2187—Underground Oil Line*

This report deals with the metallurgical examination of a length of 5-inch wrought iron pipe, approximately two feet (2') long, submitted to our laboratory for investigation and comment.

General condition of the as-received sample is shown in large photograph above. Outer surface displayed some few shallow corroded areas but was otherwise in good condition. Inner surface of the pipe sample was also in excellent condition.

ROCKWELL HARDNESS

A cross-sectional ring was prepared for hardness determinations. Hardness values, taken around the cross-sectional ring indicated a B67 hardness typical for wrought iron pipe and in lieu of tensile properties showed that the strength and ductility were likewise normal.

CHEMICAL ANALYSIS

Carbon—.025%; Manganese—.066%; Phosphorus—.230%; Sulphur—.020%; Silicon—.120%; Iron Silicate—2.82%.

SUMMARY

Results of the laboratory examination serve as positive identification of the subject sample as wrought iron. The excellent condition of this sample after more than fifty years of service is noteworthy. This report offers documentary evidence of wrought iron's corrosion control in undergound service. A. M. Byers Company, Clark Building, Pittsburgh 22, Pa.

*Name of actual installation given on request.

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WROUGHT IRON

SE-PC No. 70, July 21, 1945 (Declassified January 7, 1956), 6 pp.

Rates of corrosion of 25-12 niobium and 18-8 niobium steel in various acid media were determined. The presence of 0.4 to 1% of tributylamine or diamylamine in 60% boiling nitric acid decreased the corrosion rate of 25-12 niobium steel, particularly on repeated exposures with fresh solutions. Chromate has an inhibiting effect on the corrosion of 25-12 niobium steel by $NH_4F \cdot HF$. Systems such as 10% NH_4HF_2 — 5% $Na_2CrO_4 \cdot 4H_2O$ which might be beneficial for decontaminating the bismuth orthophosphate extraction cake by the washing technique are safely below the permissible corrosion limit. Nitric acid (1.4N) process solutions containing 0.05M fluomolybdic acid or 0.05M fluotitanic acid were found to have essentially the same corrosion effects on 25-12 niobium steel as a comparable process solution containing 0.05M fluosilicic acid. (auth)—NSA. 13730

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T-6A Report on Application Techniques, Physical Properties and Chemical Resistance of Chlorinated Rubber Coatings. NACE Technical Unit Committee T-6A on Organic Coatings and Linings for Resistance to Chemical Corrosion. (Pub. 56-6.) Per Copy, $.50.

T-6A Vinylidene Chloride Resins. A Report of Unit Committee T-6A Prepared by Task Group T-6A-3 on Vinylidene Chloride Polymers. Publication No. 57-9. Per Copy $.50.

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4.4 Chemicals Organic

4.4.2, 5.9.2, 6.2.5

Corrosion of Types 304-L and 347 Stainless Steel by Oxalic Acid. Final Report. W. L. WALKER. Hanford Atomic Products Operation. U. S. Atomic Energy Comm. Pubn., HW-40804, May 14, 1956, 10 pp. Available from Office of Technical Services, Washington, D. C.

Data pertaining to the corrosion damage incurred in the use of oxalic acid as a cleaning agent for process equipment are reported. (auth).—NSA. 14028

4.4.8

The Physical and Chemical Properties of the Alkyl Hydrazines. R. C. HARSHMAN. Paper before Am. Rocket Soc., Fall Mtg., Buffalo, Sept. 24-26, 1956. *Jet Propulsion*, **27**, No. 4, 398-400 (1957) April.

Physical and chemical properties of a large number of alkyl-substituted hydrazines are given to illustrate effects of substitution on properties of hydrazine. Hydrazine derivatives currently of interest in propellant fields are discussed. Variation in properties observed is explained in terms of normal effects of organic substitution and effects of hydrogen bonding in hydrazine. Unsymmetrical dimethyl hydrazine is less corrosive to ferrous alloys and more stable than hydrazine. Neither hydrazine nor dimethyl hydrazine produces and significant attack on aluminum. Lower alloy steels and even mild steel can be used for hydrazine and dimethyl hydrazine. Monomethyl and dimethyl hydrazine produce more severe attack than does hydrazine on many organic materials, such as elastomers. Teflon, Kel-F and polyethylene are satisfactory for both methyl hydrazines. Tables.—INCO. 14079

4.6 Water and Steam

4.6.1, 1.6

Symposium on High Purity Water Corrosion. Special Technical Pubn. No. 179, 1956, 56 pp. American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa.

Papers presented during the ASTM June, 1955, meeting at Atlantic City. The symposium was sponsored by Committee D-19 on Industrial Water. Titles of papers are: Preparation and Maintenance of High-Purity Water, F. N. Alquist; Use of Water in Atomic Reactors, H. W. Huntley and S. Untermyer; Influence of Water Composition on Corrosion in High-Temperature, High-Purity Water, Donald M. Wroughton, James M. Seamon and Paul E. Brown; Effect of Material Composition in High Temperature Water Corrosion, A. H. Roebuck; Special Corrosion Study of Carbon and Low Alloy Steels, R. U. Blaser and J. J. Owens. Discussions are included. 12749

4.6.1, 5.7.9

Change in Quality of Water Induced by Weak Direct Current. (In German.) G. SEELMEYER. *Werkstoffe u. Korrosion*, **7**, No. 1, 1-6 (1956) Jan.

Experiments were carried out on hot water supply and heating installations. Investigation evolved from controversy concerning theory that d-c current changes chemical behavior of water so that corrosive and scale-forming water becomes nonaggressive. An attempt is made to explain corrosion and scale resisting effect of weak cathodic currents. Preliminary results are given.—BL. 13442

4.6.1, 1.6, 2.5

Manual on Industrial Water. ASTM Special Technical Publication 148-B, Third Printing, 1956, 502 pp. American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pennsylvania.

The significant increase in the use of water for industrial processes makes the latest printing of the Manual on Industrial Water, a timely addition to the literature. Sponsored by ASTM Committee D-19 on Industrial Water, the manual contains a complete appendix in addition to a comprehensive discussion of water, its uses, treatment, sampling, analysis and difficulties caused by it.

The appendix lists ASTM standards relating to industrial water. It contains five methods of sampling, 41 standards, four methods of analysis, three standards for methods of reporting results, six standards for methods of test, a glossary of terms, a list of industrial water requirements and a bibliography.

Included in the latest printing are seven new methods and one important revision. Two additional proposed methods are published as additional information. No changes have been made in the chapters of the manual. 13495

4.6.1, 2.3.1

Factors in the Evaluation of the Corrosivity of Waters. (In Italian.) G. BOMBARA AND F. GIANNI. *Metallurgia Italiana*, **48**, 503-512 (1956) Nov.

Natural waters and inhibited waters and solutions studied for effects on ordinary construction steel at ambient temperature. Concludes impossibility of defining corrosivity of an electrolytic medium on a given metal unless all corrosion conditions specified; that most

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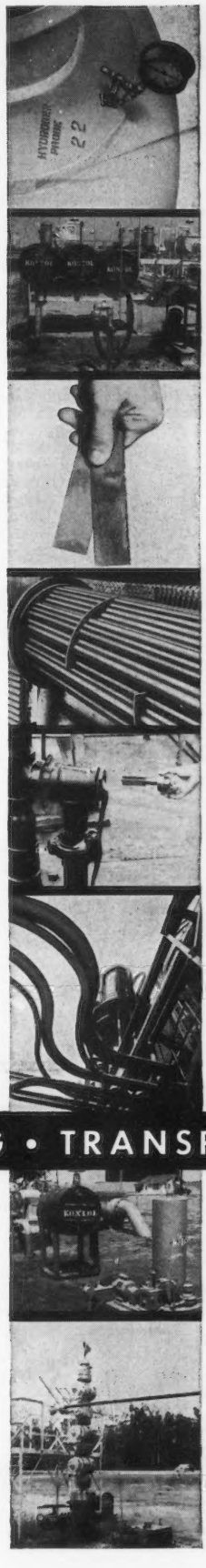

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adequate method appears to be determination of break point on cathode polarization curve. 11 references.—MR. 13502

4.6.1, 3.4.6, 3.4.7, 8.4.5

Effect of Oxygen on STR Materials at High pH, Particularly Chrome Plate. HUGH F. BEEGHLY. Westinghouse Electric Corp. U. S. Atomic Energy Comm. Pubn., WAPD-CP-287, February 15, 1954 (changed from Official Use Only May 11, 1956), 10 pp. Available from Office of Technical Services, Washington, D. C.

One of the criteria for evaluating the feasibility of operating with a primary coolant at high pH in the STR system is the ability of structural materials to resist corrosion by the coolant. Of the STR structural materials, chrome plate appeared especially susceptible to attack when both the pH and the oxygen content of the coolant were high. Chrome plated 17-4 PH steel specimens were placed in M-4 loop during a series of runs at high pH with different oxygen levels to determine quantitatively the relation between the oxygen level of the coolant and corrosion of the plate, so that maximum permissible oxygen concentration could be specified. (auth)—NSA. 13499

4.6.1

Water Treatment for Recirculating Systems. C. W. DRANE. Paper before Soc. Chem. Ind., Grangemouth, March 2, 1956. *Chemistry & Industry*, No. 46, 1367-1372 (1956) Nov. 24.

Problems encountered in recirculating systems are scale deposits, corrosion, organic growths and attack on timber or concrete. Corrosion and organic growth may be prevented by use of resistant material in condenser tubes, by chlorination and use of inhibitors. Combined effect of high pH value and loss of carbon dioxide increases tendency of calcium carbonate to come out of solution. Tendency can be reduced by addition of acid to reduce pH value and carbonate content, reduction of hardness of a makeup water in a softening plant, use of dispersives such as tannins and lignins and inhibitors such as metaphosphates. Tables, 35 references.—INCO. 13885

4.6.1, 1.6

Symposium on Industrial Water and Industrial Waste Water. ASTM Special Technical Publication No. 207, June, 1957, 52 pp. American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pa.

Six papers presented at the Second Pacific Area National Meeting, Los Angeles, September 20, 1956, under auspices of ASTM Committee D-19 on Industrial Water. Corrosion aspects of some of the subjects are considered briefly. Papers include: Three Is a Vital Number, Claude K. Rice; The First Quarter Century, Robert C. Adams; Industrial Waste Problems in Southern California, T. C. Wilson; Water Pollution Control in the Los Angeles Area, Carl B. Johnston; Sea Water Purification, O. M. Elliott; The Use of Organic Flocculants and Flocculating Aids in the Treatment of Industrial Water and Industrial Waste Water, J. K. Rice; general discussion p. 52. 14207

4.6.1, 6.4.2

Corrosion Resistance of Aluminium and Its Alloys in High Temperature Water. Report I. Relation Between Corrosion Resistance and Aluminium Purity and Corrosion Resistance of Several Aluminium Alloys. Yozo Nakamura and Satoshi Sugino. *Light Metals* (Japan), No. 22, 15-25 (1957) Jan.

The corrosion resistance in aqueous solution at high temperature and high pressure is important in materials used in nuclear reactors and chemical apparatus. An investigation was carried out on corrosion resistance of aluminum sheet (99.2 ~ 99.998% aluminum) and several aluminum alloys in aqueous solution at 250, 150 and 100 C. The following results were obtained: (1) in tests at ordinary pressure below 100 C super pure aluminum is inferior and 2S is superior in corrosion resistance. (2) Among the alloys such as 3S, 43S, M63S, Reflectal alloys and 2S-1.2% Si, 3S is the best, and Reflectal alloys the worst. (3) Addition of iron or silicon to 99.99% aluminum improves corrosion resistance with iron being more effective than silicon. Addition of both iron and silicon is even more effective. (4) Corrosion clearly proceeds along the grain boundary and the reaction product ($Al_2O_3H_2O$) of super pure aluminum falls off in layers. The corrosion which, in ordinary conditions, occurs usually around the compounds in silicon, is not observed. (5) The nickel ion is effective as an inhibitor of corrosion, but blister corrosion tends to occur on super pure Al. Fe ion delays corrosion rate at first, but induces pitting corrosion.—ALL. 14115

4.6.1, 6.4.2

Corrosion of Aluminum in High Purity Water. R. J. LOBSINGER and J. M. ATWOOD. *Corrosion*, **13**, No. 9, 582t-584t (1957) Sept.

In-reactor corrosion rates of 1245 and M-388 aluminum alloys were determined in demineralized water at temperatures up to 200 C. A correlation between corrosion rates and the effective aluminum surface temperature is presented. The effect of increased hydrogen ion concentration on corrosion rates is also discussed. 14196

4.6.10, 5.8.2, 8.1.3

Application of Organic Amine Inhibitor in Freezing Industry. Pt. I. Studies on Anti-Corrosive Properties of Amine-Type Inhibitor in Brine as a Freezing Agent. (In Japanese.) H. KOMATSU. *Corrosion Engineering*, **6**, No. 1, 35-39 (1957) January.

Fundamental experiments on organic amine-type inhibitor in freezing industry were carried out as follows:

(1) Degree of corrosion control at room temperature and 70 C by addition of 500 ppm inhibitor to the brine decreased gradually from the beginning.

(2) 500 ppm of inhibitor in tap water or brine may be obtained by adding 5 or 10 ppm each day respectively, and the anti-corrosive percentage of 60-75% can be maintained.

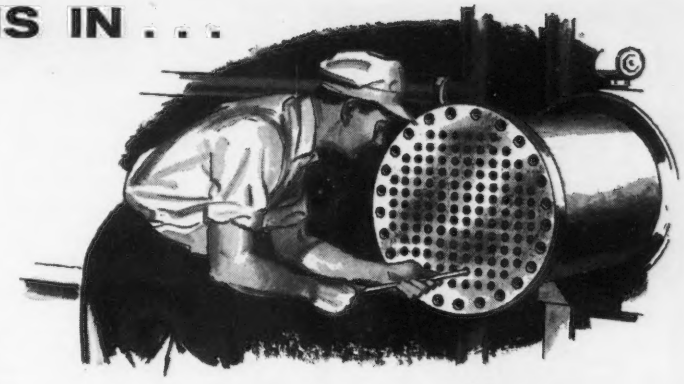
(3) In order to disperse the inhibitor in the brine satisfactorily a surface active agent (non-ionic type) was used; however, anti-corrosive efficiency was decreased.

As time passes the inhibitor will derust and expose the surface of iron.

A new ice can will not show rust, but after three months the surface of zinc plated metal will become black and brittle. Small particles suspended in brine precipitate and the brine becomes clear.—JSPS. 14231

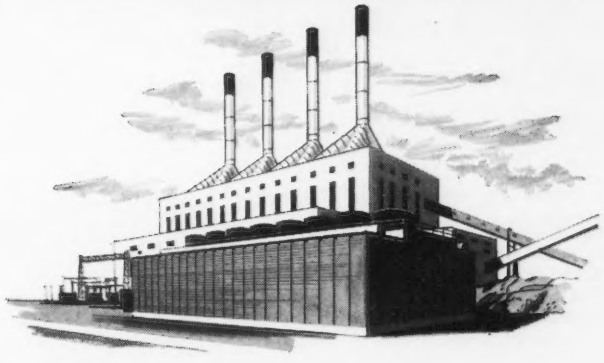
86a

WATER PROBLEMS IN . . .



heat exchangers?

pipe lines?



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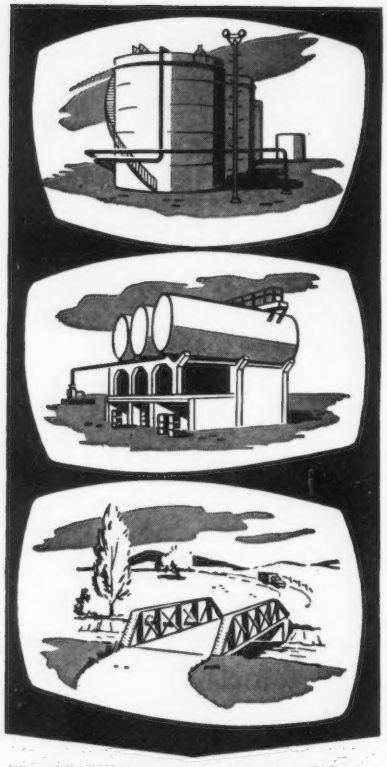

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4.6.2

Corrosion by Low-Pressure Geothermal Steam. T. MARSHALL and A. J. HUGILL. *Corrosion*, **13**, No. 5, 329t-337t (1957) May.

Corrosion tests in geothermal steam contaminated with chlorides, hydrogen sulfide and carbon dioxide are described, detailed results being given for a range of common engineering alloys.

Most engineering alloys proved moderately susceptible to steam corrosion. Titanium and austentic stainless steels (especially molybdenum-bearing varieties) were highly resistant. Stress-corrosion cracking occurred in hardened 13 chromium stainless steel, hardened low-alloy steels, one grade of austenitic stainless steel and aluminum bronze.

Physical and chemical factors influencing corrosion by the geothermal steam are discussed. 13867

4.6.2, 2.3.4

Corrosion Studies in High Temperature Water by a Hydrogen Effusion Method. M. C. BLOOM, M. KRULFELD, W. A. FRASER and P. N. VLANNES. *Corrosion*, **13**, No. 5, 297t-302t (1957) May.

A new method for the measurement of static corrosion rates in aqueous systems at elevated temperature and pressure is briefly described. Data obtained by application of the method to ferrous systems are presented. These data include (1) the corrosion rate of low carbon steel in distilled water at 600 F. (2) the effect of raising the pH in such systems, (3) the effect of thermal shock and of temperature rise on the corrosion rate, and (4) the effect of heat treatment of the metal on the corrosion rate. Comparison between the corrosion rates of low carbon steel and stainless steel and some data are included on the effect of the wall thickness of low carbon steel specimens on the rate of hydrogen effusion resulting from corrosion at 600 F. 13843

4.6.2, 6.2.5, 3.5.8

Chloride and Caustic Stress Corrosion of Austenitic Stainless Steel in Hot Water and Steam. W. LEE WILLIAMS. Paper presented at Symposium on Basic and Applied Science in the Navy, sponsored by the Office of Naval Research, Washington, D. C., March 19-20, 1957. *Corrosion*, **13**, No. 8, 539t-545t (1957) August.

The various factors which affect transgranular stress corrosion of austenitic stainless steels in steam-hot water systems are discussed. The evidence indicates that complete solution of the problem cannot be guaranteed through control of the alloy composition and condition, or through control of temperature and stress level within practical limits. Control of such factors and attention to design can reduce stress-corrosion hazards, but complete elimination apparently requires treatment of the environment to render it noncorrosive. The most serious troubles are in the steam phase in areas where intermittent wetting and steaming can cause concentration of water solids. Stress corrosion from chlorides is shown to be dependent on oxygen content and prevention of damage from this source may be obtained by limiting either the chloride level or the oxygen level. Stress corrosion from caustic solutions is not so well understood, but preliminary information indicates that the maintenance of a proper phosphate-caustic ratio may be a suitable preventive measure. 1401

4.7 Molten Metals

4.7

Corrosion Resistance of Metals and Alloys to Sodium and Lithium. E. E. HOFFMAN and W. D. MANLY. Oak Ridge National Laboratory. U. S. Atomic Energy Commission Pubn., ORNL-2271, April, 1957, 11 pp.

The austenitic (300 series) stainless steels are the most satisfactory structural materials for containing sodium in systems which are to operate at temperatures below 1500 F. Oxygen is the most troublesome impurity. No structural alloy yet discovered is satisfactory as a container for lithium in dynamic systems above 1200 F.—BTR. 14272

4.7

Corrosion and Mass Transfer by Lithium at Elevated Temperatures. E. E. HOFFMAN and L. R. TROTTER. Metallurgy Information Meeting, Ames Laboratory, U. S. Atomic Energy Commission Pubn., TID-7526 (Pt. I), February, 1957, 244-249.

Application of lithium metal as a heat transfer medium, especially as a nuclear reactor coolant. The major problem encountered, and one which is yet to be resolved, is the inability of commercially available metals and alloys to withstand the corrosive effect of lithium in dynamic systems at temperatures in excess of 1000 F. General review of the results of static, isothermal tests; recent results on 17 thermal convection loop tests conducted on iron and nickel-base alloy.—MR. 13902

4.7

Mass Transfer in Liquid Metals. W. E. DUNN and others. *A.I.Ch.E. Journal*, **2**, No. 2, 184-189 (1956) June.

Determination of the mass transfer rates for tin, cadmium, zinc and lead shapes dissolving in mercury.—BNF. 13994

4.7, 3.7.3, 2.3.7

Development of Oxidation and Liquid Sodium Resistant Brazing Alloys (Quarterly Report No. 1 for July 15, 1956 to October 15, 1956). DOMENIC A. CANONICO and HARRY SCHWARTZBART. Armour Research Foundation, Illinois Institute of Technology, Project No. B110, Contract AF33 (600)-33406, October 22, 1956, 20 pp.

Progress is reported on developing oxidation and liquid sodium resistant brazing alloys and a simple ductility test for brazed joints. Three base metals have been selected: chromium, iron and nickel. Various temperature depressants, selected on the basis of their binary eutectics formed with one of the above three metals, are being alloyed with one or more of the above elements in the effort to obtain a brazing alloy having a flow temperature within the range of 1750 to 1900 F plus the oxidation and liquid sodium resistance necessary. A technique is being studied that may permit the evaluation of ductility of a brazed joint. It is felt that the joint design and method of loading simulate service loading to the extent that significant values of ductility will be obtained, permitting the prediction of service behavior. The specimen is sectioned from a T-specimen and loaded in a tensile machine so that a fillet is subjected to tensile stresses similar to those in service. Preliminary examination of the method indicates some promise. (auth) —NSA. 13977

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4.7, 5.7.3

Inexpensive Way to Control Oxygen in Sodium Heat-Transfer Systems. I. L. GRAY, R. L. NEAL and B. G. VOORHEES. General Electric Co. *Nucleonics*, **14**, No. 10, 34-37 (1956) October.

Sodium oxides in molten sodium accelerate metal corrosion and plug systems in cold regions. Rugged, reliable devices were developed to measure 3 to 300 ppm oxygen in sodium and NaK (200 to 700 F) and to reduce oxygen to less than 10. (auth)—NSA. 13886

4.7, 3.4.9, 3.8.4

The Reaction of Molten Metal with Water. (1) Progress Report for Nov. 1—Nov. 30, 1956. (2) Progress Report for Dec. 1—Dec. 31, 1956. (3) Progress Report for Jan. 1—Jan. 31, 1957. Aerojet General Corporation, Contract AT(04-3)-44. (1) AGC-AE-29, Jan. 3, 1957, 12 pp. (2) AGC-AE-33, Jan. 28, 1957, 3 pp. (3) AGC-AE-34, Feb. 13, 1957, 7 pp. Available from Office of Technical Services, Washington, D. C.

(1) Tests have been performed to determine the reactivity of molten zirconium with water, at temperatures of 2075 to 2565C. Experiments on the corrosion rate of Zircaloy-2 in steam were completed.

(2) Explosion dynamometer tests have been performed with molten zirconium. (3) Explosion dynamometer tests were performed on 10g samples of zirconium from 3550 to 4670 F, 9g samples of NaK at 120 F, 9g samples of stainless steel at 4120 F, and aluminum at 2050 C. High-pressure high-temperature corrosion-rate tests were performed on Zircaloy-2 wire in steam at 1000 to 1200 C.—NSA. 13779

4.7

The Static Corrosion of Nickel and Other Materials in Molten Caustic Soda. J. N. GREGORY, N. HODGE AND J. V. G. IREDALE. Gt. Brit. Atomic Energy Research Establishment, Harwell, Berks, England, Rept. C/M-272, March, 1956, 15 pp.

Nickel is a satisfactory container material for molten caustic soda in the temperature range 320 to 580 C, with a mean corrosion rate of about 10 mdd. Above 580 C, corrosion is much more rapid. Of the various additions made to molten caustic soda, only lithium hydroxide gives a reduction in the corrosion rate. The mean rate of corrosion of nickel in a lithium hydroxide/sodium hydroxide eutectic mixture betwen 220 and 580 C is about 2.0 mdd, but this advantage does not extend to temperatures above 600 C. The nickel-base alloys, Inconel, Hastelloy D and Duranickel, have a slightly higher corrosion rate than commercial nickel but have the advantage of better mechanical properties. The only other resistant materials are aluminum, silver, platinum and to some extent, zirconium and the ceramics, thoria and alumina. (auth.)—NSA. 12789

4.7

Corrosion of Low Alloy Steel in Hot NaK. W. MILICH AND E. C. KING. Mine Safety Appliances Co., Callery, Pennsylvania, Memo Rept. 109, March 30, 1956, 6 pp.

Consideration is being given to the use of low alloy steels due to the difficulties encountered in the use of Type 347 stainless steel for steam generating equipment. As a preliminary experiment, to check the corrosion of such steels by liquid metals, a Type 304 stainless steel loop was revised to accommodate a section of 1 in. OD tubing composed of 2¼% chromium-1% molybdenum steel. NaK (56 wt. % potassium) at 850 F was circulated at approximately 8 ft./sec. through this tubing for four months. Four small samples (¼ in. weighed sections of the tubing) placed in an in-stream expansion tank were removed after 1, 2, 3 and 4 months' immersion time and showed penetration of 0.19, 0.09, 0.07 and 0.06 mils./yr. respectively. The section of test tubing showed no detectable weight loss after the 4-month period. With the temperature of the NaK at 850 F the oxygen content was found to be 0.032 wt. % oxygen. All results of the test run isothermally at 850 F indicated a rate of attack less than one mil per year. (auth.)—NSA. 12871

4.7

The Reactions of Molten Sodium Hydroxide with Various Metals. D. D. WILLIAMS, J. A. GRAND AND R. R. MILLER. Naval Research Lab. *J. Am. Chem. Soc.*, **78**, No. 20, 5150-5155 (1956) October 20.

Under conditions of system geometry and at temperatures up to 1000, primary reaction of sodium hydroxide with metals investigated appears to follow a pattern illustrated by equation (A) $NaOH + Metal \rightarrow Na_2O + Metal\ Oxide + H_2$. Nickel, copper, Monel, gold and probably silver and cobalt exhibit one or more of the following secondary reactions leading to a "steady-state" condition: (B) $Metal\ Oxide + H_2 \rightarrow Metal + H_2O$; (C) $Na_2O + \frac{1}{2}H_2 \rightarrow NaOH + Na$; (D) $H_2O + Na \rightarrow NaOH + \frac{1}{2}H_2$. In the presence of nickel, copper, Monel and and probably cobalt, reactions (B) and (C) are reversible. Only nickel, copper and their alloys and probably cobalt will produce definite equilibria, since the summation of equations B, C and D is the exact reverse of the primary equation A. Only these metals are protected by hydrogen additions prior to heating. Graphs, tables.—INCO. 13087

5. PREVENTIVE MEASURES

5.2 Cathodic Protection

5.2.1, 5.8.3

Cathodic Protection of Iron. M. J. PRYOR. *Nature*, **178**, 1245-1246 (1956) Dec. 1.

Tests on iron specimens in chloride solutions imply that the potential of the cathodically protected specimens cannot be below the open circuit potential of the local anodes (the condition commonly considered essential for cathodic protection to be effective). It is concluded that the usual theory of cathodic protection applies only to certain cases and that the normal function of the protective current is to reduce the rate at which iron ions leave the lattice and so encourage the build-up of protective oxide. This mechanism is similar to that proposed by the author for explaining the action of anodic inhibitors on iron.—BNF. 13691

5.2.1, 8.9.3

Protection of Underground Gas Mains from Outside Corrosion. (In Russian.) E. S. MAKHOVER. Gazovaia Promyshlennost' *(Gas Industry)*, No. 3, 20-25 (1956) March.

Electrical equipment, proper anode grounding, electrodrainage and cathodic protection used in preventing electrochemical corrosion of gas pipeline in contact with soil. Testing equipment. Diagrams, photograph.—BTR. 13610

5.2.1, 7.2

Cathodic Protection of Stainless Steel Waste Lines (Interim Report No. 1: Underground Pipeline and Structure Corrosion Study Program). R. T. JASKE. Hanford Atomic Products Operation. U. S. Atomic Energy Comm. Pubn., HW-33504, November 15, 1954 (Changed from Official Use Only November 26, 1956), 26 pp.

The practical aspects of cathodic protection of stainless steel waste lines are demonstrated.—NSA. 13618

5.3 Metallic Coatings

5.3.1

Chemically Deposited Nickel Alloy Coatings. WILLIAM J. CREHAN. *Corrosion*, **13**, No. 8, 122 (1957) August.

Some data on resistance of chemically deposited nickel alloy coatings to corrosives are given and techniques of application and heat treatment described. 14256

5.3.1

Protection Against Oxidation of High-Temperature Alloys Using Multi-Phase Diffusion Processes. (In French.) H. BUCKLE. Paper to Journees d'Automne, 1955. *Rev. Met.*, **54**, 16-22 (1957) Jan.

Multi-phase diffusion process is one in which protecting metal coating interdiffuses with base metal as a consequence of thermal treatment. Application of process to protect tungsten and molybdenum and nickel-chromium-type alloys (e.g., aluminizing of Nimonic 75: illustration of etched section through aluminum-coated Nimonic 75, showing formation of nickel-aluminum alloy is discussed.—INCO. 14194

5.3.2

Properties of Sprayed Zinc Coatings. E. GEBHARDT and H. D. SEGHEZZI. *Electroplating*, **10**, No. 3, 81-85 (1957) March.

The author describes experiments designed to show up differences between wire and powder sprayed zinc surfaces on steel prepared in various ways. He concludes that there is no significant difference in surface between the two plating methods on the same base but that a quartz blasted surface has better adhesive properties than one that has been grit blasted.—ZDA. 14265

5.3.2

Atmospheric Exposure of Electroplated Lead Coatings on Steel. A. H. DUROSE. Paper before Am. Soc. Testing Materials, Symp. on Properties, Tests and Performance of Electrodeposited Metallic Coatings, Spr. Mtg., Buffalo, Feb. 29, 1956, and 2nd Pacific Area Nat'l. Mtg., Los Angeles, Sept. 19, 1956. ASTM Special Technical Publication No. 197, 1957, 66-90.

Discusses inspection and evaluation of panels that had been exposed at New York, Kure Beach, State College, Pa. and Tela, Honduras. Coatings included various thicknesses of lead from fluoborate and sulfamate baths applied to steel, copper-flashed steel and copper; lead-tin alloy coatings; electroplated zinc; and hot-dipped lead, terne and zinc. Results of visual inspection, corrosion rate of lead, corrosion damage to steel as measured by steel weight loss, corrosion

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damage to steel as measured by change in tensile properties and analysis of protective film formed at New York are considered. Tables, graphs.—INCO. 14201

5.3.2

Sprayed Aluminum Coatings. G. TOLLEY. *Chemistry and Industry*, No. 21, 464 (1956).

One of several letters concerning cathodic protection by sprayed aluminum coatings. The specific electrical conductivity of sprayed aluminum being approximately 1/5 that of the cast metal and interconnected porosity being probably 8-15%, Tolley considers that cathodic protection by sprayed aluminum coatings cannot be ruled out and that the filling of pores with corrosion product may also be a factor.—MA 13854

5.3.2

Composition of Sprayed Alloy Coatings. F. A. CHAMPION AND G. W. WALKIDEN. *Chemistry and Industry*, No. 3, 76-77 (1956) January 21.

Laboratory spray tests on aluminum alloy sprayed coatings on steel and on high-strength aluminum alloys. Optimum purity for "pure" aluminum coatings is 99.5% U. R. Evans, in a subsequent letter (*ibid.*, No. 12, 195-196 (1956) March 24) draws attention to the fact that the cathodic protection of bare steel by sprayed aluminum is experimentally established.—BNF. 13966

5.3.2, 2.3.7

Hardness of Electrodeposited Tin-Nickel (65% Tin) Alloy on Brass. V. R. RAMANATHAN. *Bull. Inst. Metal Finishing* (Trans IMF), **6**, No. 3, 1-7 (1956) August.

Using microindentation technique, it is found that if the thickness of coating is sixteen times the depth of penetration, measured hardness is characteristic of the deposit and independent of base metal or load. Deposits from fresh solutions have 710 DPH.—BNF. 13946

5.3.2, 3.5.5

Permeation of Gases Through Electrolytic Nickel Deposits. II. Determination of the Effect of Several Variables on the Intrinsic Permeability of Nickel Deposits to Gases. D. T. EWING, J. M. TOBIN AND D. G. FOULKE. Paper before Electrochem. Soc., Boston Mtg., October 3-7, 1955. *J. Electrochem. Soc.*, **103**, No. 12, 648-651 (1956) Dec.

Conditions of temperature, current density and pH used when plating from a Watts' bath were each varied independently to determine effect on intrinsic permeability of deposit. Total nickel, chloride and boric acid concentration of a Watts' bath were studied similarly and effect of various addition agents which tend to produce bright deposits from Watts' baths was determined. Several bath impurities increased intrinsic permeability of nickel deposit. Graphs, tables.—INCO. 13985

5.3.2, 6.2.4

The Effect of Silicon in a Low-Alloy Steel on the Adhesion of Heavy Nickel Plating. J. J. DALE AND H. K. LUTWAK. *Trans. Inst. Metal Finishing*, **34**, 133-138 (1957); *Bull. Inst. Metal Finishing*, **7**, No. 2, 133-138 (1957) Summer.

Occurrence of adhesion failures in heavy nickel plating of parts made from silicon-containing alloy steel led to theory that anodic etching of such steels in sulfuric acid solution oxidizes the silicon in the dissolved steel layer to silicic acid and thereby forms film which prevents proper adhesion of nickel deposit. Experience with nickel-chromium-molybdenum steels (En25 type) containing 0.10-0.35 silicon is considered. Theory was confirmed by improved adhesion of nickel deposited after anodically etched steel was treated with sodium hydroxide solution which dissolves the silicic acid. Recommended procedure is outlined.—INCO. 14255

5.3.2, 6.3.9

Metallographic Study of Electroplated Coatings of Chromium and Nickel on Molybdenum. R. J. RUNICK. Paper before Electrochem. Soc., Pittsburgh, October 9-13, 1955. *J. Electrochem. Soc.*, **104**, No. 2, 74-79 (1957) Feb.

Microstructure of single- and multilayer coatings of electroplated nickel and chromium on molybdenum were studied to determine why coatings failed when heated in air. Specimens were tested at 900 C. In single-layer coatings chromium was less subject to bonding failure than nickel. Cracking of chromium coatings was major cause of failures, but good protection by chromium is possible if layer of chromium-molybdenum alloy is formed at interface. Electroplated nickel did not form cracks and abridged flaws in base metal, but adhesion was not satisfactory. Layer of nickel over chromium covers faults extending through chromium plate and prevents chromium from cracking. Formation of blisters between nickel and chromium layers was major cause of failure of this type of coating. Chromium plate over nickel plate is not desirable. Photomicrographs.—INCO. 13829

5.3.2, 2.3.7, 3.5.5

Effect of Corrosion on the Gas Permeability of Nickel Electrodeposits. D. G. FOULKE AND J. M. TOBIN. Paper before Am. Electroplaters' Soc., 43rd Ann. Conv., Washington, D. C., June 17-22, 1956. *Tech. Proc. AES*, **1956**, 234-238.

To determine plating failures due to porosity and relation of gas permeability, authors used modification of low pressure- constant overpressure method and photographic technique as used in AES Projects 6 and 13. Initial permeability was determined for bright, Watts' type, cobalt-nickel, sulfamate, and nickel + chromium electrodeposited films. Results are presented for corrosion of these films in 10% sulfuric acid and for Pinner-Pierce anodic corrosion test in 3% sodium chloride solution. Although it has been demonstrated that consistent results can be obtained by this method and that there is definite difference between metallurgical nickel and electrodeposited nickel with respect to permeability of helium gas, it is not possible to correlate gas permeability of thin foils required for such permeability measurements with service corrosion characteristics of nickel electrodeposits, in that Watts and cobalt-nickel deposits (considered more corrosion resistant than organic nickel deposits), showed both greater initial porosity and more rapid increase in porosity under accelerated corrosion tests than did organic bright nickel deposits. Tables, graphs.—INCO. 13591

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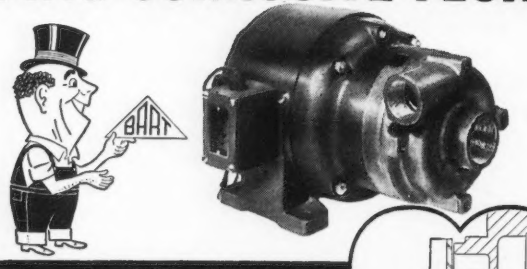

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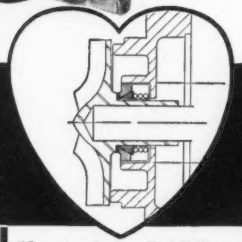

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5.3.2

Electrolytic Protection of Steels by Cadmium-Titanium Alloy Deposits. (In French.) R. MICHEL. *Corrosion et Anti-Corrosion*, **4**, No. 1, 36-39 (1956) Jan.

Electrodeposition of cadmium-titanium (no composition given), from a cadmium cyanide/sodium cyanide/sodium hydroxide bath at 18-20 C containing three (unnamed) derivatives of titanium and organic addition agents, is recommended for certain applications, e.g., protection of magnetic circuits, springs, etc. Cadmium-titanium can be plated on to iron, steel, brass and copper; it cannot be plated on to pure aluminum.—BNF. 13638

5.3.2, 2.3.7, 1.6

Symposium on Properties, Tests, and Performance of Electrodeposited Metallic Coatings. ASTM Special Technical Publication 197, 1957, 129 pp. Am. Soc. Testing Materials, 1916 Race St., Philadelphia 3, Pennsylvania.

The volume is extensively illustrated and contains comprehensive tabular data. Prepared under the auspices of ASTM Committee B-8 on Electrodeposited Metallic Coatings, the Symposium contains the following significant papers: Introductory Remarks, W. L. PINNER; History of ASTM Committee B-8, WILLIAM BLUM; The Corrosion Behavior and Protective Value of Copper-Nickel-Chromium and Nickel-Chromium Coatings on Steel, C. H. SAMPLE; Evaluation of Methods Available for Measurement of Surface Luster of Electroplated Coatings, G. B. BOWMAN; Recommended Practices for Cleaning Prior to Electroplating, S. SPRING; A Comparison of the Corrosion Behavior and Protective Value of Electrodeposited Zinc and Cadmium Coatings on Steel, C. H. SAMPLE, A. MENDIZZA AND R. B. TEEL; Evaluation of Phosphate Coatings over Electrodeposited Zinc, A. L. ALEXANDER; Evaluation of Testing Methods for Supplementary Coatings, R. E. HARR; Atmospheric Exposure of Electroplated Lead Coatings on Steel, A. H. DUROSE; The Standard Salt-Spray Test: Is It a Valid Acceptance Test?, A. MENDIZZA. 13750

5.3.2

The Deposition of Nickel by Chemical Reduction. A. McL. AITKEN. Paper before Sheet & Strip Metal Users' Tech. Assoc. Conf. on Modern Processes, London, April 26-27, 1956. *Sheet Metal Inds.*, **33**, No. 351, 439-443, 455; disc., 455-460, 494 (1956) July.

Covers history of development of electroless nickel plating leading to Kanigen process, chemical composition, structure, physical properties, heat treatment, mechanical properties, materials suitable for plating, applications, limitations and economic considerations. Table compares corrosion resistance of as-deposited Kanigen and Kanigen heat treated to 750 C in various corrosive media. Photomicrographs.—INCO. 13477

5.3.2, 2.3.7

Stress in Electrodeposits. R. PINNER. *Electroplating*, **9**, No. 12, 391-396 (1956) Dec.; *ibid.*, **10**, No. 1, 7-11 (1957) Jan.

Causes of stress and its importance in determining coating properties; various methods of measuring stress; normal values of stress for different baths; effect on stress of substrate, deposit thickness, solution composition and impurities, stress relieving agent and operating conditions such as temperature, current density, pH, etc., in various electroplating processes. Effect of stress on crack formation. corrosion and fatigue. 55 references.—BNF. 13670

5.3.2, 3.5.8, 3.7.4

Strain Figures Appearing on the Surface of Copper Electrodeposits Subjected to Fatigue. M. SUZUKI. *J. Inst. Metals*, **85**, Pt. 5, 206-208 (1957) Jan.

Effects of microstructure of underlying metal upon flecks and strain figures appearing on surface of electrodeposited copper subjected to fatigue. Specimens were copper-plated α brass, $\alpha+\beta$ brass, sand cast 6 tin bronze and 0.9 carbon mild steel. Flecks do not occur at random positions but appear in region of grain boundaries of metal beneath. Grain boundaries on which flecks appear run parallel to directions of the planes of the maximum shear stress. Maximum shear strain at surface of electrodeposited copper coatings below which no flecks occur has certain limiting value; critical shear strains are tabulated. Photomicrographs.—INCO. 13470

5.3.2, 5.4.5

Sprayed Metal as a Base for Paints. H. S. INGHAM. *Corrosion*, **13**, No. 4, 252t-256t (1957) April.

The use on steel of thin metallized coatings of zinc and aluminum is discussed in detail. A number of recommendations are made regarding surface preparation. Consideration is given to the effect sprayed metal coatings have on the application, appearance and performance of the paints applied over them. The cause and remedies for paint failures are discussed with particular attention paid to underground power plant applications. The selection of paints and primers for a given sprayed metal and the use of thinners are discussed briefly. 13448

5.3.2, 5.4.5

Protective Zinc Coatings. (In German.) K. A. VAN OETEREN-PANHAUSER. *Metall*, **10**, No. 15/16, 711-715 (1956) August.

A comparison of two zinc-coating methods (sprayed zinc plus paint and metallic zinc paints), which are regarded as alternatives, for massive purposes such as steel structures, bridges, etc. Nature of coating, corrosion resistance, life, costs, etc., based on published literature.—BNF. 12617

5.3.2, 5.9.4, 5.4.2

Hard Coatings and Surfaces for Metals: Materials and Methods Manual No. 134. R. J. FABIAN. *Materials & Methods*, **45**, No. 1, 121-140 (1957) Jan.

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TP-1D Sour Oil Well Corrosion. *Corrosion* August, 1952, issue. NACE members, $.50; Non-members $1 Per Copy.

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wear and corrosion properties, metals that can be treated and chief advantages and limitations for major types of hard coatings and surfaces. Included in review are: hard facings applied by variety of welding processes; carburized, nitrided, cyanided or carbonitrided, siliconized and chromized diffusion coatings; flame- and induction-hardened surfaces; electrodeposits of hard and ductile chromium, nickel and rhodium; anodic coatings for aluminum and magnesium; and sprayed coatings of metal, ceramics and tungsten carbide. Comprehensive chart summarizes material in text. Tables list typical properties and effect of temperature on hardness of nickel electrodeposits, hardness and tensile strength of sprayed metals (including 18-8), and properties of ceramic coatings vs. stainless steel.—INCO. 13151

5.3.2, 6.2.3

Mass Spectrometric Examination of Hydrogen in Chromium-Plated Steel. C. Levy and G. A. Consolazio. Paper before Electrochem. Soc., Boston, October 3-7, 1954. *J. Electrochem. Soc.*, **103,** No. 11, 624-627 (1956) Nov.

Specimens of chromium-plated SAE 1015 steel were examined for hydrogen in mass spectrometer. Peak heights obtained in arbitrary units were plotted as function of time. Hydrogen evolution was studied at 100-800 C. Evolution of hydrogen from steel and chromium-plated steel was measured for constant temperature rise of 2 C/min. Below 350 C hydrogen evolved almost exclusively from chromium plate, while above 490 C evolution occurred primarily from the steel. Major portion of hydrogen available for release in both specimens was liberated after 80 minutes of heating. Graphs.—INCO. 13295

5.3.4

Basal Plane Development in Electrodeposited Hexagonal-Close-Packed Metals: Zinc, Titanium and Zirconium. W. R. Opie. *J. Metals* (Trans. AIME), **8,** No. 9, 1192-1194 (1956) Sept.

X-ray and micrographic examination of zinc deposits from aqueous electrolytes and titanium and zirconium from fused salt baths. A strong tendency exists for development of hexagonal faces which are actually the basal planes of the hexagonal-close-packed lattice: when this development is pronounced, the deposits are very bright, mirror-like and brilliant to the eye.—BNF. 13337

5.3.4

Effects of Impurities and Purification of Electroplating Solutions. I. Nickel Solutions. 10. The Effect and Removal of Manganese. A. J. Smith and R. J. Rowe. Paper before Em. Electroplaters' Soc., 43rd. Ann. Conv., Washington, D. C., June 17-21, 1956. *Tech. Proc. AES*, **1956,** 46-49.

Effect of manganese on appearance, adhesion, ductility, hardness, corrosion resistance and throwing power of nickel deposited from Watts' solution (pH 2.2 and 5.2), nickel-cobalt alloy bath and organic bath. Watts panels exhibited smoothing effect on high current density areas with increasing manganese concentrations. Small increase in throwing power was noted for the two bright solutions. Removal of manganese is not affected by either high pH precipitation methods or low current density electrolysis.—INCO. 13399

5.3.4

The Effect of the Substrate on the Crystallization of Metallic Films. F. I. Metz and R. A. Lad. *J. Phys. Chem.*, **60,** 277-280 (1956) March.

The effect was studied of surface heterogeneity and sample preparation on the crystallization behavior of metallic films. Thin films of gold, silver and zinc deposited by vacuum evaporation on alkali halide single crystal surfaces were found to be composed of crystallites of two size ranges. The possible relation of the nucleation sites to mosaic boundaries and surface cracks is discussed.—ZDA. 13274

5.3.4

The Metallographic View. Part XXIX. Nitriding the Lower Alloy Steels. H. E. Boyer. *Steel Processing*, **42,** No. 12, 700-701, 708 (1956) Dec.

Although best nitriding properties and hardest cases can generally be obtained by use of special alloy steels, a number of more conventional steels such as AISI 4140, 6145 and 4340 will lend themselves to nitriding. Chromium-vanadium or chromium-molybdenum types are preferred since addition of nickel inhibits nitriding action to some degree. Carbon content should be about 0.40%. Depth-hardness charts illustrate results obtained by nitriding hardened and tempered 4140 at 975 F for 48, 24 and 7 hours. Microstructures of edge sections of same specimens are shown. In addition to heat and wear resisting characteristics afforded by nitrided steels, a much higher degree of dimensional control can be maintained with nitriding method.—INCO. 13517

5.3.4

Temperature-Resistant Hard Surface Layers of Nickel-Chromium-Iron Alloys. G. Faber. *Schweiz. Archiv angew. Wiss, u. Tech.*, **23,** 14-19 (1957) Jan.

Attempted application of sigma phase (intermetallic iron-chromium compound) to production of hard scale- and wear-resistant surface layers. Pure sigma phase is highly brittle but when sigma phase particles are embedded in austenitic matrix, a certain amount of impact strength is retained. Production of surface layers by facing techniques, using special types of welding rods and by chromium plating of austenitic materials, followed by diffusion-annealing is discussed. Work was done on precipitation-hardening of hard-surfacing alloys containing 30-40 chromium, 13 nickel, 0.5 niobium, 1 silicon, balance iron. Study was made of sigma phase production in these alloys and precipitation-hardening phenomena explained. Hard-facing tests, effects of heat-treatment, chromium plating of material containing 15 nickel, 16 chromium, 10 cobalt, 1 titanium, 3 tungsten and 13 nickel, 17 chromium, 3 tungsten titanium-stabilized steel and production of hard surface layers by diffusion-annealing are discussed.—INCO. 13777

5.3.4

Electrodeposition of Titanium. Part 3. W. E. Reid, Jr., J. H. Connor and A. Brenner. National Bureau of Standards. U. S. Wright Air Development Center, September, 1956, 18 pp. Available from Office of Technical Services, U. S. Dept. of Commerce, Washington 25, D. C. (Order PB 121721).

Electrodeposition of titanium from organic solvents was shown in previous research to be most effective from baths consisting of an ether and a soluble reactive titanium compound such as titanium borohydride. This report describes further study of the baths in an effort to increase titanium content of the alloys over the 6.5 percent previously obtained. The possibility of using sodium or potassium borohydride instead of lithium borohydride to prepare titanium and zirconium borohydrides was examined. Among new compounds prepared for use in the titanium-aluminum alloy bath were chloroborohydride etherates of titanium. Some work was done on the use of organometallic aluminum compounds in a titanium alloy bath. Codeposition of halnium and thorium with aluminum from the borohydride bath was studied in comparison with the titanium-aluminum alloys. In addition, a number of reactions between reactive organic compounds and titanium salts were performed in a search for a suitable titanium plating bath. 13681

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TP-19 Corrosive Effects of Deicing Salts—A Progress Report by Technical Practices Committee 19, *Corrosion*, January, 1954, issue. NACE members $.50; Non-members $1 per copy.

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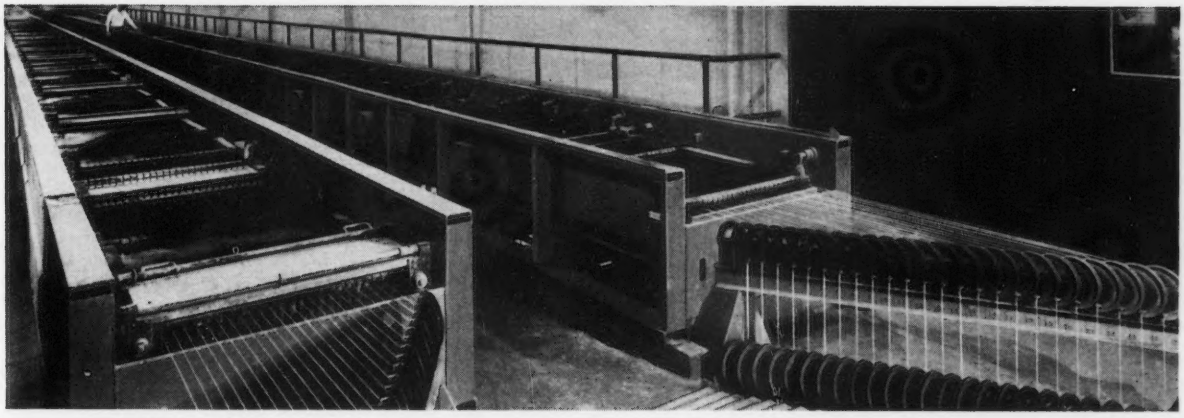

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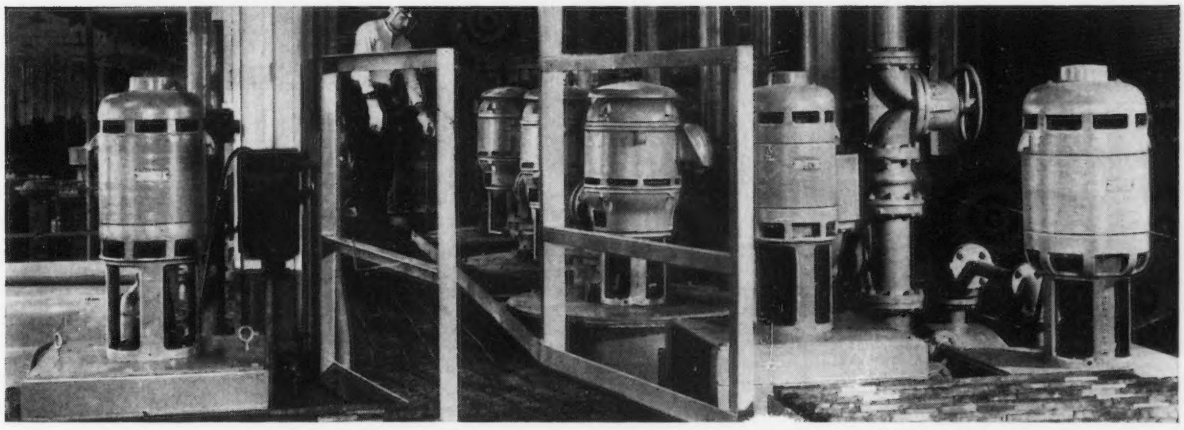

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5.3.4

The Influence of Some Process Variables on the Reflectivity and Surface Appearance of Electrolytic Tinplate. R. MILLS. *Bull. Inst. Metal Finishing* (Trans. IMF, **6**, No. 3, 8-17 (1956) Autumn.

Laboratory investigations indicate that characteristics of the thinner electrolytic tin coatings are particularly influenced by surface finish of steel base and by all but the lightest pickling treatments. Upper limit of current density for production of acceptable coatings is extended by increased temperature of electrolyte and of relative cathode-electrolyte velocity.—BNF. 13945

5.3.4

Plating of Tungsten by an Oxidation-Reduction Cycle. M. G. CHARLTON AND G. L. DAVIS. *Bull. Inst. Metal Finishing* (Trans. IMF), **6**, No. 3, 28-39 (1956) August.

Tungsten is deposited by means of an oxidation-reduction process in the vapor phase if a tungsten source is kept at a high temperature in an atmosphere of hydrogen and water, the body to be coated being kept sufficiently close to the tungsten to be heated to above about 700 C. Mechanism of reaction is discussed. Adherent tungsten coatings are rapidly produced and the method is claimed to be superior to others.—BNF. 13943

5.3.4

Some Notes on the Electrodeposition of Antimony. A. H. DU ROSE. *Tech. Proc. Am. Electroplaters' Soc.*, **1956**, 151-156, 297.

Investigation of antimony deposits (fluoride bath) as decorative and protective coatings. Antimony lacks ductility or cohesive strength. Good but not consistently reproducible corrosion protection was obtained if undercoats of copper (or nickel) followed by lead (or tin) were used. Results usually good in salt spray or acetic acid salt spray and outdoor exposure but questionable under industrial winter outdoor conditions. Antimony tarnishes outdoors unless protected by chromium. Adhesion to various basis metals, discussed from crystallographic point of view.—BNF. 13934

5.3.4

Effects of Impurities and Purification of Electroplating Solutions. I. Nickel Solutions. II. The Effect and Removal of Calcium. A. J. SMITH AND R. BACON. *Plating*, **44**, No. 2, 186-187 (1957) Feb.

American Electroplaters' Society Research Project 5. Calcium up to 700 ppm had no effect on appearance, ductility, throwing power, hardness, adhesion and corrosion resistance of nickel deposited from Watts' solutions of 2.2 and 5.2 pH, organic bright solution and nickel-cobalt bright solution. Spectrographic analyses of stripped deposits revealed no calcium.—INCO. 13838

5.4 Non-Metallic Coatings and Paints

5.4.2

Metal Protective and Radiation Reflective Ceramic Coatings. CLARENCE L. HOENIG, TRACY A. WILLMORE AND DWIGHT G. BENNETT. Univ. of Illinois. U. S. Wright Air Development Center, Tech. Rept. 56-140, January, 1956, 32 pp.

The objective of the work described was to develop ceramic coatings that would, in one application, protect heated metal from corrosion and at the same time reflect a significant amount of incident radiant energy. A total of 36 ceramic coatings were prepared in which four matrix, or bonding, glasses and four refractory, radiation-reflective ceramic aggregates were investigated. The radiation-reflective components were fused magnesia, calcined diaspore, stabilized zirconia and calcined ceria. It was found that calcined ceria was superior in properties of wettability, stability, low solubility and sustained radiation reflection during long heating. When used with a matrix glass of proper thermal expansion, ceria aggregate coatings were found to function effectively in a one-coat application on Type 347 stainless steel. It appeared that it would be necessary to develop matrix glasses of somewhat greater fusibility to permit such coatings to function as well as low alloy steel. (auth.)—NSA. 14133

5.4.2, 3.8.4

Investigation of Wetting Properties of Several Metals Under Controlled Atmosphere. O. S. THOMPSON, JR. AND D. H. HALL. Thesis submitted to College of Ceramics, Alfred Univ., May 14, 1956, 18 pp.

Theories on adherence are reviewed and factors involved in wetting are discussed. Primary objective of paper was to observe, under the same conditions, the contact angle variation of a conventional ground coat frit (minus cobalt, nickel and manganese oxides) on enameling iron, Inconel, Type 304 and Type 430 in helium and in air at 750 C. Observations pertaining to oxidation of the metals were made. Preliminary investigation with a cobalt glass showed that the cobalt glass did not tend to wet uniformly. Excessive oxidation tended to cause bubbling and pitting in enamel. Oxidation of metal tended to increase wettability; enameling iron oxidized more than other metals. In inert helium atmosphere, order of increasing wettability (for frit minus cobalt, nickel and manganese oxides) was: enameling iron, Inconel, Type 304 and Type 430. In oxidizing atmosphere order of increasing wettability was: Inconel, Types 304 and 430 (equal) and enameling iron. Diagram of apparatus, photos of specimen, table, bar graph.—INCO. 14029

5.4.2, 2.3.2

How Do You Handle Low Temperature Enamels? Porcelain Enamel Inst., Shop Practice Forum, Univ. of Illinois, November 7-9, 1956. *Ceramic Ind.*, **67**, No. 6, 68-70 (1956) Dec.

Forum covered pros and cons of low temperature porcelain enameling, furnaces and tooling required, properties of the enamels, test methods, nickel deposition process and electrostatic color application. J. Finley Jr. (Philco Corp.) found that to obtain the required 0.02-0.03 grams/sq. ft. of nickel, the nickel solution specifications are: 1 oz. per gal. single nickel salts, temperature of 150-155 F rigidly maintained and sodium hypophosphite as required. Addition of the sodium hyophosphite is discussed. F. W. Smith described accelerated water tank test and presented corrosion data for enamel linings. Others participating in forum included G. Howe, R. F. Rush, H. Tripp, R. S. Dale, G. Tuttle, J. T. Roberts, J. R. Crandall, J. A. Schiefferle and M. P. DuBovy.—INCO. 13545

5.4.2, 6.4.2

Vitreous Enamels on Light Metals. (In French.) F. J. BIECHLER AND J. J. MEYNIS DE PAULIN. *Corrosion et Anti-Corrosion*, **4**, No. 7, 241-245 (1956) July-August.

Necessary properties in a vitreous enamel. Compositions proposed for seven enamels for aluminum and aluminum alloys. Results of tests on enameled specimens of six light alloys to determine resistance to citric and acetic acid, sodium carbonate, salt spray, thermal shock, water; also appearance and hardness.—BNF. 13505

5.4.3

Acidproof Vessel Construction with Membrane and Brick Linings. A Report of NACE Technical Unit Committee

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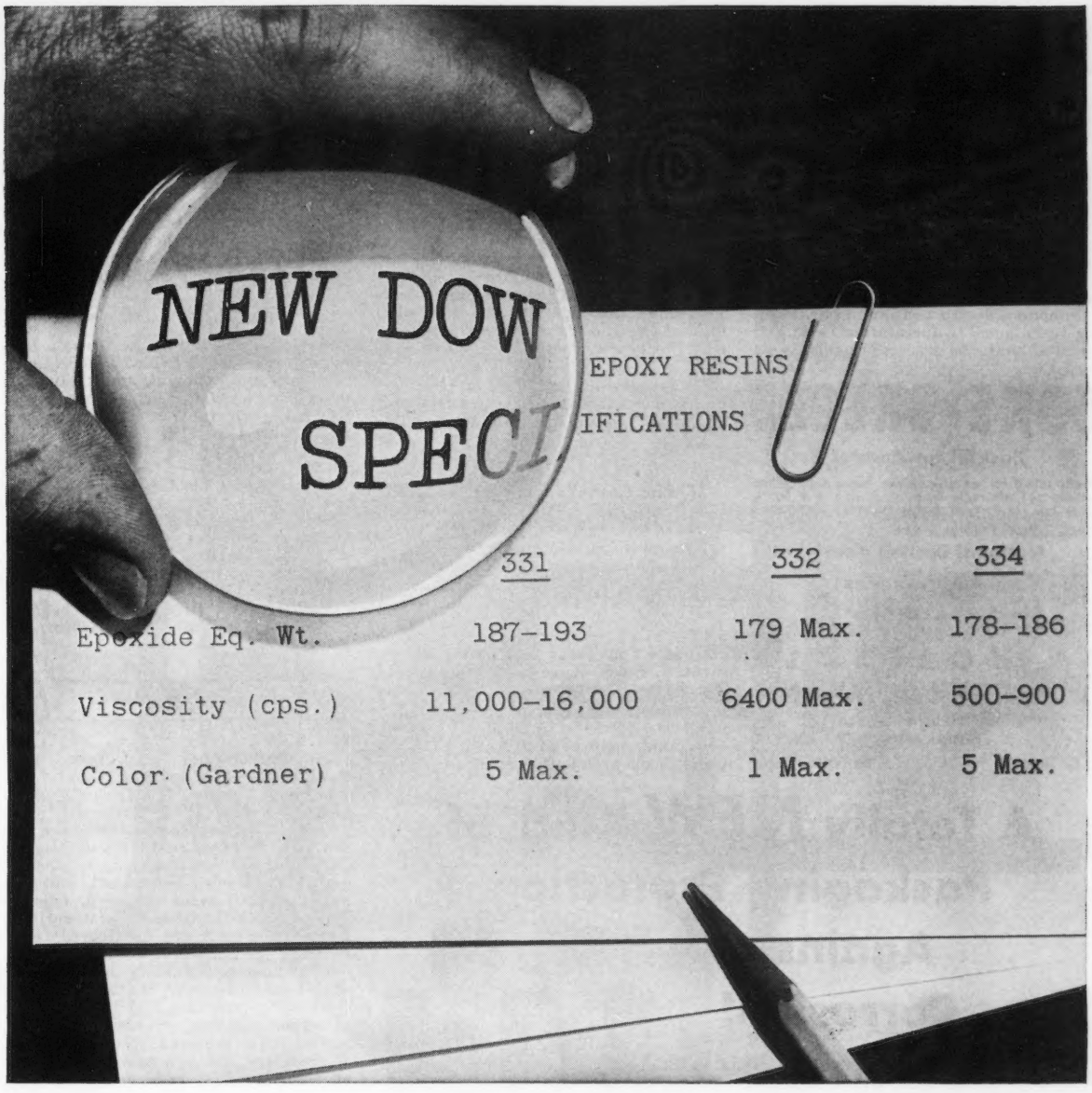

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T-6K on Corrosion Resistant Construction with Masonry and Allied Materials (L. R. Honnaker, Chairman). *Corrosion,* **13,** No. 3, 195t-204t (1957) March.

Following a brief history of the development of brick-membrane vessel construction and the cements used, types of vessels and supporting structures are described. Design formulae are given. Recommended specifications and techniques are described briefly. Membrane linings commonly used are listed and described, technique of holiday testing given and cements considered with respect to their suitability in different kinds of construction and for different types of service.

Function, design considerations, jointing techniques, temperature criteria and physical characteristics of principal brick types related to construction are described.

Tabular data on ratings of different kinds of membrane (including lead) versus two representative temperatures and numerous corrosive acids, alkalis, salts, gases, organic materials and bleach solutions are given. Stability of principal cements versus representative temperatures and corrosives are tabulated as are physical and mechanical properties of typical cements, working time for cements, physical properties of red shale brick and relative cost data. 13131

5.4.5

Silicones and Their Application in Protective Coatings. HAROLD L. CAHN. *Official Digest Federation Paint and Varnish Production Clubs,* **28,** 590-602 (1956) July.

Manufacture, chemistry, application, typical formulations and water repellent qualities of commercial products.—BTR. 12746

5.4.5

Silicone Coatings for Metal Products. L. F. STEBLETON. *Materials and Methods,* **45,** 112-115 (1957) February.

General discussion of silicone coatings and their uses where resistance to heat, moisture and corrosive conditions are advantageous.—MR. 14138

5.4.5

Update Your Ideas on Painting Equipment. J. BIGOS. Based on a paper before 8th Plant Maintenance & Eng. Conf., Cleveland. *Chem. Eng.,* **64,** No. 4, 300, 302, 304, 306 (1957) April.

Painting may be eliminated by using glass block or translucent plastic sheet, colored cement, glazed tile and alloy metals, or by letting steel rust with increase in thickness as corrosion allowance. Costs for increasing steel thickness in industrial atmosphere are compared with painting costs. Preparation of metal surface (weathering, wire brushing) and pretreatment methods (phosphate, etc.) are considered. Guide summarizes selection of paint systems for steel structures, incidental steel equipment and incidental steel work; information on oil-base paints, alkyd paint, phenolics, chemically resistant paints, rust preventive compounds and bituminous coatings is outlined.—INCO. 14157

5.4.5

Vehicle Finishing. A. L. MULLER. *Ind.-Lack.-Betrieb,* **24,** No. 11, 261-265 (1956).

Surface pretreatment, application systems and ventilation arrangements are covered, with some emphasis on economic aspects.—RPI. 14170

5.4.5

Water Reducible Coatings for Industrial Finishing. G. ALLYN. *Products Finishing,* **20,** No. 10, 40-45 (1956) July.

Author discusses acrylic emulsion system which is one of three types of water based systems. Properties and applications are summarized. Similar article by author: Acrylic Coatings for Metal Products. *Materials and Methods,* **44,** 106-109 (1956) December. 13962

5.9 Surface Treatment

5.9.1, 6.3.6

Colored Finishes for Copper. A. I. HEIM. Copper & Brass Res. Assoc. *Product Eng.,* **27,** No. 12, 135-142 (1956) Dec.

Chemical conversion coatings for coloring for copper, brasses and bronzes are discussed. Solution compositions are given for brown, blue, black, antique, patina, Tiffany green and verde finishes. Embossed or patterned metal surfaces supplied by mill are considered. Bulk finishing methods reviewed include barrel finishing or tumbling, ball burnishing, bright dipping, matte dipping, electrolytic polishing, acid pickling, blast or vapor cleaning, grinding, polishing, buffing and brushing. Natural copper alloy colors are produced by varying alloy composition; table giving compositions for matching copper alloys includes nickel-copper alloys.—INCO.

5.9.2, 2.6, 6.4.2

The Behavior of Some Aluminum Alloys in Mixtures of Chromic and Phosphoric Acid. (In German.) K. M. CARLSEN. *Aluminum,* **33,** No. 2, 101-103 (1957) Feb.

Rolled samples of polycrystalline high purity, aluminum (99.99%), commercial purity aluminum (2S), aluminum-1.04% nickel alloy, aluminum-0.93 iron alloy, aluminum-1.95% copper alloy and aluminum-1.02% silicon alloy were subjected to the corrosive attack of a hot solution of 4% weight chromium trioxide and 10% weight phosphoric acid and the resulting effects were observed by micrography. Among the alloys tested the aluminum-silicon alloy sample exhibited by far the best corrosion resistance and it is assumed that this behavior is a result of an oxidation process of the silicon atoms and of their incorporation into the protective layer rather than merely an electrochemical phe-

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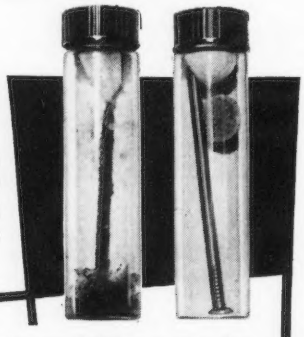
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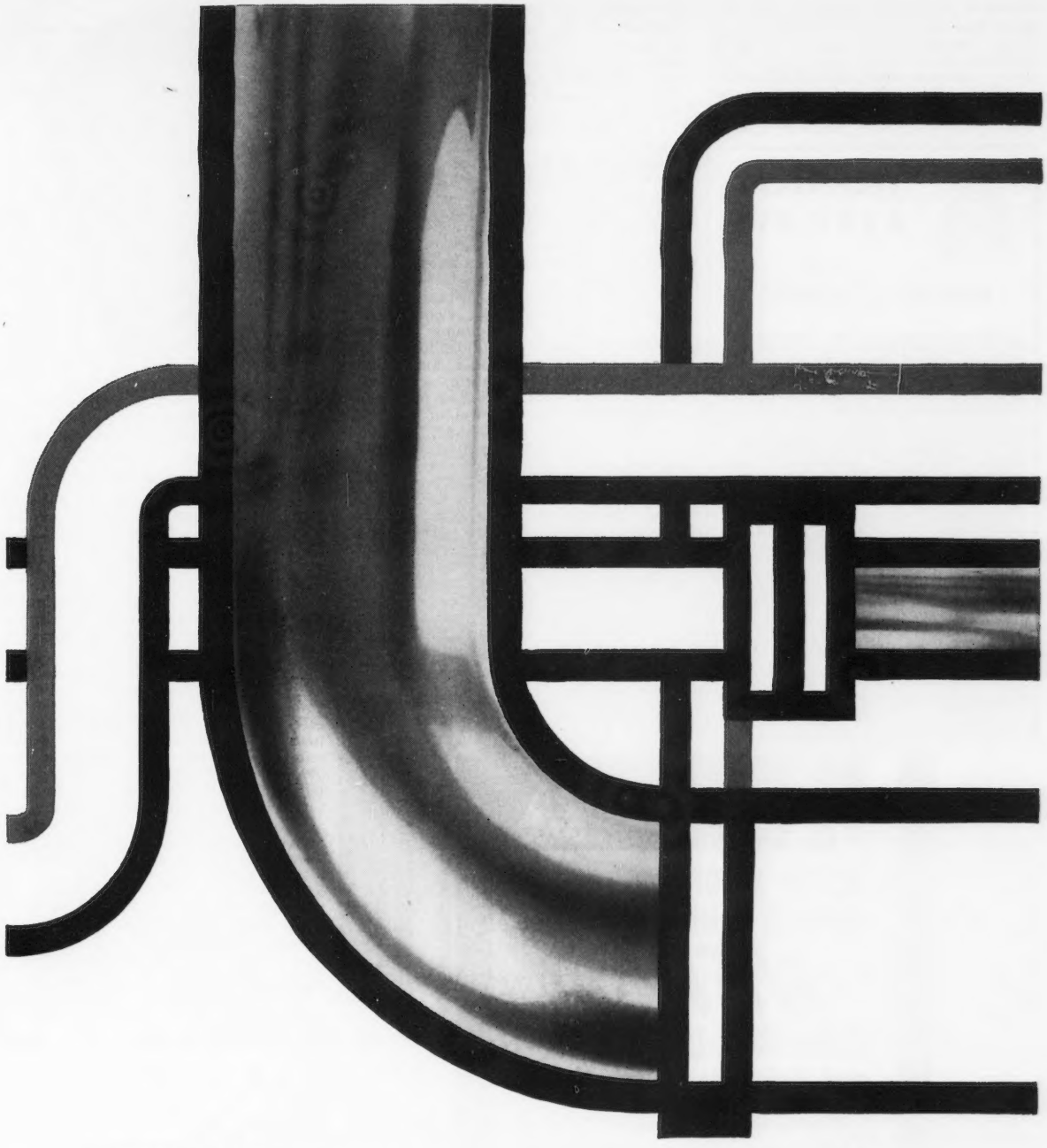

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nomenon. Generally speaking, the base metal was more or less attacked in all alloys investigated, except in those aluminum-silicon and high purity aluminum samples which were cathodically polarized. Since the acid mixture described is used for the dissolution of corrosion products to facilitate the inspection of the metal itself, it should be borne in mind that, in most cases, the metal stock is attacked as well and the conclusions thence derived should therefore be accordingly corrected.—ALL. 13765

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5.9.2, 6.4.4

Chemical Brightening of Aluminum. A. W. BRACE. *Metal Ind.*, **90,** No. 8, 147-150, 153 (1957) Feb. 22.

The fundamentals and operation of the chemical brightening process for aluminums are surveyed and its possibilities as it appears in its present state of development, are assessed. Following the introduction of some basic principles the composition of two distinct types of chemical brightening mixtures—(a) those based on phosphoric acid, and (b) those containing ammonium bifluoride (or hydrofluoric acid) and nitric acid—are analyzed. The functional relationships between weight loss in aluminum, on the one hand, and immersion time, temperature, delay in rinsing and aluminum content, on the other hand, are graphically represented. The effect of metal purity and anodic film thickness on total and specular reflectivity seems to indicate that for such applications where an appearance similar to chromium plate is required, super purity aluminum should be used. For architectural applications and costume jewelry, however, lower purities (99.5-99.8%) are quite satisfactory. The brightening equipment, technique of anodizing subsequent to chemical brightening and the various methods of testing film thickness, brightness, abrasion and corrosion resistance are studied.—ALL. 13759

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5.9.2, 8.3.3, 6.4.2

(Corrosion Rates of) Cleanser for Aluminum (Alloy) Dairy Plant. W. A. WRIGHT. *Dairy Eng.*, **73,** No. 6, 167-171 (1956).

Susceptibility of aluminum to attack by alkalis and the inhibiting action of sodium silicates are discussed. Test results on corrosion rates and appearance when commercial purity aluminum alloy S1C-½H, wrought aluminum-1-1.5% manganese alloy NS3-H, wrought aluminum-1.75-2.75% magnesium alloy NS4-½H, and wrought aluminum-0.4-1.5% magnesium, aluminum-0.75-1.3% silicon alloy HS10-WP were fully immersed in 1, 2, 3, and 4% $Na_2SiO_3 \cdot 5H_2O$ soln. at 140 and 18 F (60 and 75 C) for 6, 8, 24, 48 and 72 hours are given in tables and show that $Na_2SiO_3 \cdot 5H_2O$ soln. *per se* even at 4% concentration and 18 F may safely be used. A blend of a mild detergent for use in farm dairies is suggested as well as a blend for the mechanical washing of milk cans which is non-corrosive to both aluminum and tinplate.—MA. 13711

5.9.3

Cleaning of Metals by Sandblasting Prior to Painting. V. CHARRIN. *Trav. Peintures*, **12,** No. 2, 48-50 (1957).—RPI. 14248

5.9.3

Preparation of Metal Surfaces by Flame Cleaning before Painting. L. MENDEL. *Chim. Peintures*, **19,** Nos. 5, 7, 189-194, 277-283 (1956).

Methods of surface preparation are described with particular mention of flame-cleaning with the oxy-acetylene torch. The advantages of this gas mixture over oxy-coal-gas, oxy-hydrogen and oxy-propane and of the method generally over other surface preparation techniques are discussed. Commercial torches and auxiliary equipment are described and illustrated. Practical examples of applications are included, with an account of costing.—RPI. 14098

5.9.4

Anodic Oxidation by Processes Other Than Sulphuric Acid. (In French.) CHARLES ETIENNE and FRANCOIS FLUSIN. *Rev. Aluminium*, **34,** No. 241, 295-301 (1957) Mar.

The oxidation-dissolution equilibrium which, for a given electrolyte, governs the conditions of electrolysis (concentration, temperature, current density, time) can be modified by a change in the nature of the electrolyte; it follows that the above factors should also be altered. The oxide films thus obtained can offer special properties. The authors describe the electrolytes where sulfuric acid is the main constituent with additions of acetic acid, glycerin, chromic acid, magnesium chloride, oxalic acid. They also describe chromic acid and oxalic acid baths.—ALL. 14158

5.9.4

Testing for Phosphate Treatment of Iron and Steel. (In Japanese.) First Sub-Committee (Sec. A) of the Committee of Preventing Corrosion, Japan Society for the Promotion of Science. *Corrosion Engineering*, **6,** No. 2, 78-84 (1957) March.

Test pieces cut from rimmed steel plate were treated with seven domestic-made solutions for phosphate coating and evaluated by testing methods specified in USA specification so-called MIL-C-12968 (ORD).—JSPS. 14252

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5.9.4

Effect of Operating Conditions in the Sulphuric-Acid Anodizing (of Aluminum) on the Formation and Properties of the Oxide Film. D. LENZ. *Aluminum*, **32**, Nos. 3, 4, 126-135, 190-201 (1956).

Lenz reports the results of a comprehensive research into the effect of different variables, such as bath composition, current density, voltage and operation temperature on the thickness, structure and various properties of the oxide film. In the first part, pp 126-132, he deals in the main with the effect of these variables on the thickness of the non-porous primary film, on the dimensions of the individual cells and their shape, with special reference to the shape and size of the specimens. In the second part, pp. 133-135, he deals mainly with the optical properties of oxide films on super-purity metal, in particular the effect of variables on its reflectivity. Some hints are given concerning the choice of metal and its pretreatment, the most suitable current density for any given thickness of film, the best bath temperature and the most suitable sealing process for various purposes. The third part, 190-201, deals with the corrosion-resistance of the final oxide film, in particular to weak acid and alkali solutions and to moist industrial atmospheres. Two different current densities of 1.0 and 2.5 amp./dm.^{2} at 10-20 V. and a bath temperature of 17-18 C were used and with two total current inputs of 20 and 40 amp. min./dm.^{2}, corresponding to estimated film thickness of 0.0064 and 0.0127 mm. Sealing was done by the following methods: in superheated steam at 150 C for 20 min.; in saturated steam at 100 C for 20 min.; in boiling distilled water for 30 min.; and in boiling distilled water +0.5% water-glass for 30 min. The media used for the corrosion tests were N/2 hydrochloric acid and 5% sodium hydroxide solutions, both at room temperature and with agitation, and an artificial moist industrial atmosphere, containing sulfur dioxide and carbon dioxide (concentrations not given) maintained at 50-55 C. Best results were shown for films produced with low current density and sealed with superheated steam. Results are given in tables and graphs. 23 references.—MA 13250

5.9.4

Effect of the Method of Anodic Passivation and Electrolyte Concentration on the Porosity of Aluminum Oxide Film. A. F. BOGOYAVLENSKIL AND N. V. SILETSKAYA. *J. Applied Chem.*, USSR (Zhur. Priklad. Khim.), **29**, No. 8, 1295-1297 (1956).

A letter. 13516

5.9.4, 6.3.5

Anodic Oxide Films. V. Kinetics of Formation of Anodic Oxide Films on Niobium Space Charge and the Tafel-Slope Anomaly. VI. Application of Dewald's Theory to Niobium. LAWRENCE YOUNG. *Trans. Faraday Soc.*, **52**, No. 4, 502-514; 515-521 (1956).

Part V. Anodic polarization of niobium produces intereference-colored oxide films which grow by ionic conduction under the influence of the electrostatic field F($\sim 10^6$V./cm.) set up in the oxide by the applied voltage. The current $i \propto e^F$, and dln F/di is substantially independent of temperature. Space-charge effects were indicated by the dependence on the previous current density of the initial F when, after a period on open circuit, a changed current density was applied. Impedance measurements with an AC bridge indicated that ionic space-charge increased with decreasing current density; the distribution of excess metal-ions is frozen in on ceasing formation and only slowly adjusts itself; the non-stoichiometry causes electronic conductivity. Part VI. These results are examined in the light of the theory proposed by Dewald [*J. Electrochem. Soc.*, **102**, 1 (1955)]. The observed dependence of space charge on current density indicates that the jump distance for diffusion into the oxide is less than that for diffusion through the oxide. 24 references.—MA. 13699

5.9.4, 6.3.6

The Microgeometry of the Surfaces of Electropolished Alpha-Brass. PIERRE A. JACQUET. *Compt. rend.*, **242**, No. 16, 1990-1993 (1956)

Jacquet studied by intereference contrast with two polarized waves the influence of the factors of electrolysis on the micro- and submicro-profiles of surfaces of an α-brass (37%Zn), electropolished in phosphoric acid. The results confirm that contrary to certain theories, the polishing process is not independent of the specific reactivities of the crystallographic planes and their eventual distortion. [See also Jacquet, ibid., **241**, 798 (1955)].—MA. 13630

5.9.4, 6.4.2

Investigations on the Reaction of Aluminium with Water. (In German.) D. ALTENPOHL. *Aluminium*, **33**, No. 2, 78-91 (1957) February.

As a result of chemical reaction of aluminum with boiling water a hydrated oxide: $Al_2O_3 \cdot 1H_2O^{1to5}$, or boehmite layer is formed on the metal surface, which, if certain conditions of the reaction are satisfied, may be used as a means of general corrosion-protection. The author conducted extensive research to determine the conditions which are capable of producing maximum corrosion resistance of such boehmite layers. To this effect the influence of minute differences in the purity of boiling water, the formation of boehmite films by the repeated use of the same water and the effect of various additions to super purity water, together with the pH value, on the rate of growth of such layers, was studied. Finally, the suitability of boehmite layers produced in an alkaline medium for corrosion-protection was investigated. The protective value of the films formed under different conditions was tested by exposing the samples to tap water of various temperatures. The results are summed up as follows: (1) colorless boehmite layers formed in water of less than 1.5% German hardness provide full protection against corrosion by tap water at temperatures higher than 70 C; (2) the aggressivity of tap water increases with decreasing temperatures; (3) at room temperature and up to 50 C only the films produced under optimum conditions remain resistant. Boehmite layers formed by boiling for 2 to 4 hours in a 0.1 N ammonium hydroxide solution proved to have the highest protective value. Such samples tested for 1½ years in cold, running or stationary, hard tap water, showed no traces of corrosion whatsoever. However, the presence of heavy metal ions, in a proportion higher than 1 mg/1 of water, especially when the boehmite film is interrupted by minute discontinuities, considerably reduces its protective effect.—ALL. 13696

5.9.4, 6.2.3, 3.8.4

Features of Anodic Behaviour of Steel in an Electropolishing Electrolyte for Low Density Polarizing Currents. (In Russian.) G. S. VOZDVIZHENSKY, A. SH. VALEYEV AND G. A. GORBACHUK. *Doklady Akad Nauk*, SSR, **108**, No. 2, 299-301 (1956). 13700

5.9.4, 5.4.5, 3.5.9

Loss of Water of Hydration from Phosphate Coatings Determined Radiometrically. STANLEY L. EISLER, JODIE DOSS AND W. DENNIS MCHENRY. U. S. Arsenal, Rock Island, Ill., Rock Island Arsenal Lab. *Org. Finishing*, **17**, No. 5, 5-9 (1956) May.

Steel phosphated with heavier-type coatings of iron, zinc or manganese phosphate showed blister formation under subsequently applied paint films that required baking at temperatures above 450 F. This phenomenon could not be attributed to 'alkaline peeling' but was thought to arise from the loss of water of hydration from tertiary zinc or manganese phosphate at elevated temperatures. To investigate this possibility, steel specimens were phosphated in four different phosphating baths containing tritium as radioactive tracer and activity measurements were made after

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heating cycles ranging from 150 to 500 F in the presence and absence of air. Loss of water of hydration was calculated from the radioactive counting rates before and after heating and was found to take place at relatively low temperatures. This confirms the suspected cause of blistering of baked paint coatings applied over phosphated steel.—PDA. 13583

5.9.4

Spot Marks on Colour Anodized Sheet Aluminium and Methods of Avoiding Them. (In German.) F. E. FALLER. *Aluminium*, **33**, No. 2, 91-94 (1957) February.

The surface defect of anodized aluminum described consists of randomly distributed light and dark circular spots ranging in diameter from 0.1 to 0.5 mm. To determine the cause of such blemishes metallographic studies and laboratory tests were conducted and the results thereof are presented. It is pointed out that the occurrence of such surface defects may be avoided if, subsequent to anodizing, the product is thoroughly rinsed, then, neutralized with ammonia or a bicarbonate solution, followed by a second rinsing. The use of hard, chloride-containing rinsing waters should be avoided. By carrying out the anodizing treatment in this manner the gradual enrichment of the coloring bath with chlorides and sulphuric acid can be prevented and the prescribed pH value of the bath will remain constant. A tentative interpretation of the process is given.—ALL. 13781

6. MATERIALS OF CONSTRUCTION

6.2 Ferrous Metals and Alloys

6.2.1

Tubes of Heat-Resisting Alloys. (In Russian) V. S. MIKHEEV. Vestnik Akad. Nauk S.S.S.R. *(News of the Academy of Sciences of the USSR)*, **26**, 40-42 (1956) July.

The technological properties and use of triple ferrite alloy 24 to 26% chromium, 4.5 to 6% aluminum, 0.5 titanium and iron with small admixtures of carbon, sulfur, phosphorus, silicon, manganese and nickel developed for use in high-temperature pyrolysis of gaseous and liquid hydrocarbons are reported. The chemical interaction fused iron, chromium, aluminum and titanium into a compact ingot with strong heat resistance and oxidation losses of 0.06 g/m² per hr. at 1200 degrees. The alloy does not show carbonization tendencies during carbon pyrolysis, permitting the prolonged chemical treatment of materials. New alloys of iron with 60 to 65% chromium and 6 to 8% aluminum, with heat resistance to temperatures up to 1350 to 1400C were also recently developed and are now tested as material for reactors, etc.—NSA. 13273

6.2.1, 2.2.2

Effect of Alternate Corrosion and Abrasion on Some Ferrous Metals. J. DEARDEN and J. D. SWINDALE. *J. Iron Steel Inst.*, **185**, Pt. 2, 227-234 (1957) Feb.

Resistances of 11 ferrous metals to atmospheric corrosion, to abrasion and to certain combinations of both, were compared. Metals included panel steel, Cor-Ten, normalized spring steel, hardened spring steel, Ni-Hard, Hadfield's manganese steel, white iron containing chromium, grey cast iron, rail steel, mild steel and chill cast iron. Panels were first exposed in industrial atmosphere until control panel had achieved standard increase in weight, then brought indoors and subjected to controlled abrading with emery cloth on finishing machine. Resistance to corrosion was reduced by abrading dust and increasing frequency of abrasion increased corrosion rate, except for grey cast iron. Resistance to abrasion alone was related to defined equivalent carbon content of steels tested rather than their hardness. Marked increase in loss per abrasion occurred in all materials when corro-

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sion alternated with abrasion. Three white cast irons showed exceptional resistance to corrosion. Tables, graphs. —INCO. 14117

6.2.2

Growth of Gray Cast Iron. F. N. Tavadze and I. A. Bairamashvili. Liteinoe Proizvodstvo *(Foundry Production)*, No. 5, 15-18 (1956) May.

Study of qualitative and quantitative influence of graphitization and oxidation on growth of gray iron. To prevent distortion of linear dimensions by scale formation, end surfaces of air-tested specimens were electroplated with nickel. Results show that oxidation processes are in no measure reflected in microstructure of vacuum-treated gray iron, which indicates insignificant influence of occluded gases upon oxidation. Growth of gray iron is affected predominantly by oxidation processes. Treatment of gray cast iron in air is associated with a marked increase in hardness, which indicates occurrence of structural changes. Graphs, photomicrographs, tables.—INCO. 14013

6.2.2

Corrosion Tests of Sintered Iron. (In German.) A. Bukowiecki and U. A. Engster. *Schweiz. Archiv angew. Wiss. u. Tech.*, **23,** 78-83 (1957) March.

Corrosion tests of two types of sintered iron in 3 percent sodium chloride/water solution. Comparison with iron sheets of the same chemical composition. —BTR. 14264

6.2.2

Tensile and Fatigue Tests on Normalized Pearlitic Nodular Irons. G. N. J. Gilbert. *J. Research and Development, Brit. Cast Iron Research Association*, **6,** No. 10, 498-504 (1957) Feb.

Tensile and fatigue properties of as-cast and normalized pearlitic nodular irons with 1.63-2.56 silicon, are compared. Normalizing increases proof stress, tensile strength and hardness and elongations in tensile test are improved. Improvement in properties depends on rate of cooling in air after treatment and on normalizing temperature used. Fatigue properties are increased slightly by normalizing. Tables, graphs, photomicrographs.—INCO. 14114

6.2.2

Latest Developments in Spheroidal-Graphite Iron. W. W. Braidwood. Paper before Inst. Brit. Foundrymen, London Branch, January, 1956. *Foundry Trade J.*, **100,** No. 2066, 321-330 (1956) May 17.

Describes recent progress in spheroidal-graphite development with particular reference to methods now established for treatment of metal by the use of metallic magnesium. Various techniques and apparatus for addition of magnesium in different forms are discussed including sealed ladle of Metallgesellschaft A.G., modified sealed ladle invented by Klingbeil and the Pont-a-Mousson pressure chamber. A new nickel-free alloy has been developed which appears to be as efficient as nickel-magnesium and halves cost of magnesium treatment. Need for suitably equipped foundries for production of spheroidal graphite iron and competition with malleable founding are discussed. Heat treatment and mechanical properties such as hardness, tensile properties and ductility are considered. Advantages of graphite in form of spheroids as opposed to flakes include resistance to fire-cracking, thermal shock resistance, and improved damping capacity. Other characteristics such as ready machinability, wear resistance and corrosion resistance are discussed and application of spheroidal cast iron including centrifugally-cast pipe, are discussed. Molding methods applicable are reviewed. Diagrams, illustrations.—INCO. 12735

6.2.2, 3.7.2

Heat Resisting Property of Ductile Cast Iron. S. Kawamoto, M. Iwase, H. Kominami and T. Ikawa. *Hitachi Hyoron*, **38,** No. 11, 97-103 (1956) Nov.; *Library Abst. Bull.*, Japan, No. 3, III-14 (1956) July-December.

To improve heat resistance of ductile iron, effect of adding copper, chromium, silicon and nickel to the iron on its resistance to oxidation and growth was investigated. Resistance to oxidation was much improved by adding silicon. High silicon ductile iron (5 silicon) had a higher resistance to oxidation than austenitic ductile iron containing 18 nickel. Resistance to oxidation of austenitic ductile iron with 5 silicon with similar to 18-8. Resistance to growth of ductile iron was much improved by copper and chromium due to stabilizing effect on the pearlite precipitated at Ar_1 transformation. Large amounts of silicon and nickel gave the same effect since the latter retarded Ac_1 transformation.—INCO. 13613

6.2.2, 7.1

On the Wear of Cast-Iron Cylinder Liners. P. A. Heller and W. Glaser. *Giesserei*, **43,** 505-507 (1956) August 30.

Literature review supported by new results on wear of austenitic nickel-containing cast iron, spheroidal graphite iron and chromium-containing irons.—INCO. 13584

6.2.3

The Structure, Deformation, and Fracture of Pearlite. K. E. Puttick. *J. Iron Steel Inst.*, **185,** Pt. 2, 161-176 (1957) Feb.

Some features of pearlite structure of EN42 plain carbon eutectoid steel revealed by electron microscopy are described. Precipitate is formed in ferrite on aging isothermally transformed pearlite at 140-300C; this may be carbide or cementite. In homogeneity detected in pearlitic cementite may be due to alloy segregation, possibly of manganese. Types of growth faults distinguished include: linear discontinuities in cementite lamellae, branch crystallization, deviations of lamellar orientation, rod-like growth and growth of cementite round inclusions. Deformation is accommodated by fine slip in ferrite parallel to lamellae where resolved shear stress is sufficiently high, or by slip transverse to cementite in unfavorably oriented colonies. Shear in latter case is accompanied by plastic deformation of cementite and some ferrite/cementite interfacial slip. Ferrite slip may also follow zig-zag path in early stages of deformation. Fracture surfaces revealed patterns which may be explained by brittle fracture across pearlite colonies, following paths determined by previous slip. Photomicrographs.—INCO. 14047

6.3 Non-Ferrous Metals and Alloys—Heavy

6.3.3

Volume Change and Gas Evolution on Heating Electrolytic Chromium. K. A. Moon and G. A. Consolazio. Watertown Arsenal, U. S. Army, January, 1956, 15 pp. Available from Office of Technical Services, U. S. Dept. of Commerce, Washington, D. C. (Order PB 121768).

When electrolytic chromium is heated in vacuum or in an inert atmosphere to a sufficiently high temperature, changes are induced which include a pronounced decrease in hardness, loss of gases and irreversible shrinkage of the specimen. A mass spectrometer and a dilatometer were used to study the interrelationships of these changes. In the experimentation, specimens of electrolytic chromium were heated in a vacuum at the rate of 3 degrees per minute up to 1100 C in an attempt to correlate the evolution of gases with irreversible shrinkage and the underlying structural changes which are known to occur. Water, hydrogen, and nitrogen gas evolutions began near 100, 300 and 800 C, respectively. The rate of irreversible shrinkage increased near 400 C, passed through a maximum and then increased again near 700 C. Electrolytic chromium specimens with ribbon-like inclusions of hydrous chromic oxide began to shrink near 100 C. Investigators tentatively concluded that the shrinkage near 100C was due to dehydration of the ribbon-like inclusions, while the shrinkage near 600 C was due to recrystallization and related processes. They also concluded that the shrinkage near 400 C was apparently caused by dehydration of very finely dispersed inclusions, but not by inclusions of hydrous chromic oxide that were blamed in earlier research. 13884

6.3.5

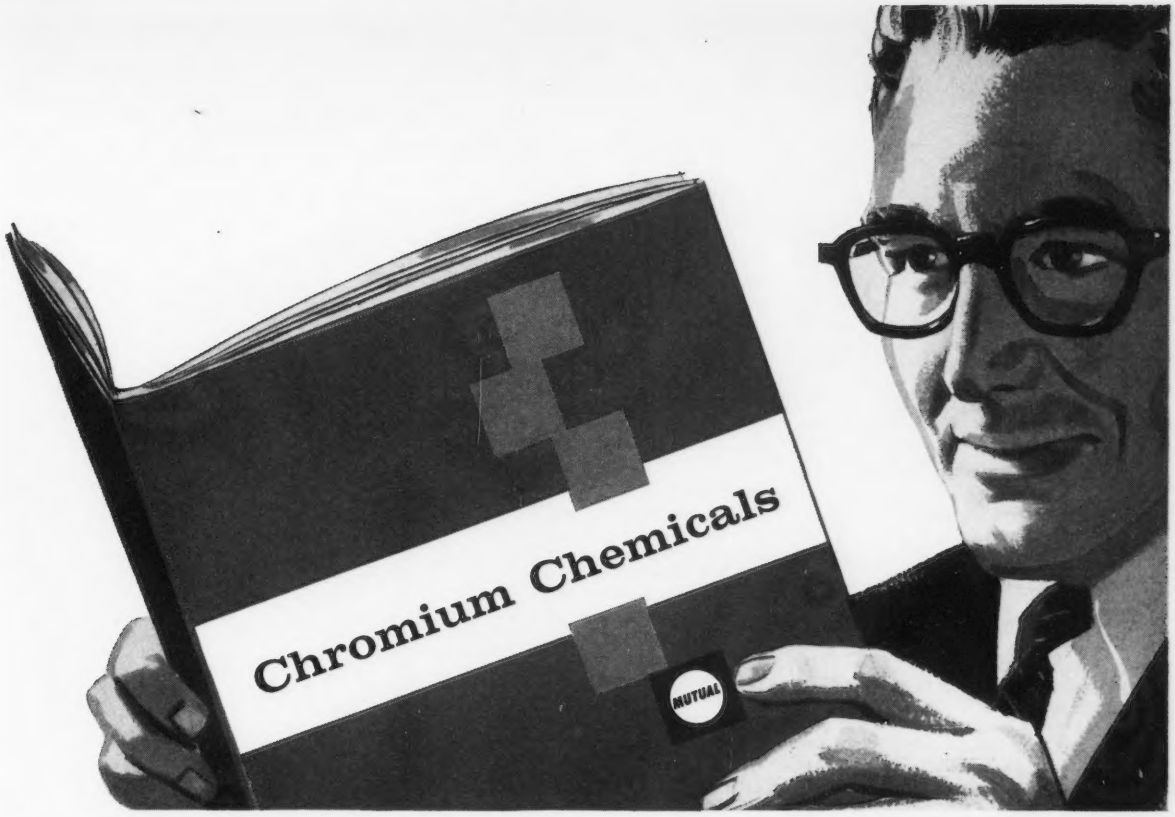
The Development of Niobium. A. B. McIntosh. *J. Inst. Metals*, **85,** Pt. 8, 367-372 (1957) April.

Niobium is of interest for atomic energy purposes because of its high melting point, excellent compatibility with uranium, good high-temperature strength and suitable physical and mechanical properties. The metal shows excellent corrosion-resistance to all acids except hydrofluoric, but is rapidly penetrated by caustic alkalis. With pure liquid metals niobium is satisfactory for service at 600 C and upwards, but the corrosion-rate is markedly increased by small oxygen concentrations. The possible development of alloys possessing high-temperature strength and oxidation-resistance is discussed and it is concluded that alloys with selected transition metals with interstitial solute additions may be of interest for both purposes. (auth).—MA. 14127

6.3.5

Investigation of Some Niobium-Base Alloys. Stan J. Paprocki and John T. Stacy. Battelle Memorial Inst. U. S. Atomic Energy Comm. Pubn., BMI-1143, October 31, 1956, 18 pp. Available from Office of Technical Services, Washington, D. C.

Twenty-seven niobium-base alloys, containing 5 wt.% of aluminum, chromium, iron, molybdenum, nickel, tantalum, tungsten, vanadium or zirconium and with an addition of 0, 9.5, or 19.0 wt.% titanium, were examined for workability, ductility, hardness at room temperature and 1600F and oxidation resistance at 1800F. Addition of titanium generally improved workability, increased hot hardness and promoted oxidation resistance. Some exceptions to this pattern were noted: the hardest alloy at 1600F, niobium 5 wt.% zirconium, softened with added titanium and



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the oxidation resistance of niobium 5 wt.% molybdenum and the niobium 5 wt.% vanadium alloys was not increased by additions of titanium. (auth)—NSA. 14008

6.3.5, 3.5.9

High-Temperature Oxidation and Contamination of Niobium. WILLIAM D. KLOPP, CHESTER T. SIMMS and ROBERT I. JAFFEE. Battelle Memorial Institute. U. S. Atomic Energy Comm. Pubn., BMI-1170, February 9, 1957, 25 pp. Available from Office of Technical Services, Washington, D. C.

The oxidation and contamination rates of niobium in oxygen and in air were measured in the temperature range 600 and 1200C. The oxidation curves in oxygen were linear and the rate constants were correlated by an Arrhenius-type plot. The heat of reaction was 5410 cal/mole from 600 to 1100C; above 1100C the reactions were rapid and the rates could not be correlated to the Arrhenius-tvpe plot. The activation energy for diffusion of oxygen in niobium was calculated from contamination data. Weight-change curves of niobium in air were also linear, with lower rates than in oxygen. The heat of reaction was, from the reaction rate data, 10,100 cal/mole from 600 to 1200C. Contamination in air-reacted niobium was similar to that in oxygen-reacted niobium, suggesting that oxygen is the primary diffusing contaminant. (auth)—NSA. 14083

6.3.6

Fracture Characteristics of Copper-Base Alloys. N. C. HOWELLS and E. A. LANGE. U. S. Naval Research Laboratory, April, 1957, 12 pp. Available from Office of Technical Services, U. S. Department of Commerce, Washington, D. C. (Order PB 121933).

Drop-weight and Charpy V tests conducted at temperatures between 210F and minus 300F showed that the fracture relationships of 15 Navy copper-base alloys were different from those of steel in that a Charpy V energy level of 10 ft.-lb. does not indicate a brittle condition for copper-base alloys. The alloys with Charpy V energy values from 3 to 10 ft.-lb. were found to plastically deform even in the presence of a sharp notch. Only a copperbase alloy with a tensile elongation value below 2 percent was shown to fracture in a brittle manner. However, the ductility of high-tensile manganese bronze became very low at temperatures below minus 100F. High-tensile manganese bronze approached a brittle condition at temperatures below minus 150F. 14121

6.3.6, 3.5.8

Crack Paths in Fatigued Copper. D. S. KEMSLEY. *J. Inst. Metals,* **85,** Pt. 9, 420-421 (1957) May.

Cracks in fractured copper fatigue specimens were found to be inter-crystalline in specimens tested at high stress and transcrystalline in those fractured under low stress. Both types of crack were produced at intermediate stresses. All tests were made in a rotating-cantilever machine at 6000 c/m. Table, 10 references.—INCO. 14296

6.3.6, 3.5.8

A Note on the Brittle Intergranular Fracture of Beta-Brass. S. HARPER. *J. Inst. Metals,* **85,** Pt. 9, 415-416 (1957) May.

Stress concentrations at grain boundaries, in conjunction with a rapid rate of straining, are shown to be essential factors in causing intercrystalline failure at high temperatures in ordered beta-brass. Table.—INCO. 14290

6.3.10, 3.7.2

A Study of the Possibility of Reinforcing of High-Temperature Alloys by Addition of Refractory Powders (Period Covered April 1955 to April 1956). JOHN D. BURNEY. P. R. Mallory and Co., Inc. U. S. Wright Air Development Center, Tech. Rept. 56-190, April 18, 1956, 41 pp. Available from Office of Technical Services, Washington, D. C. (Order PB 121474.)

A study of the possibility of reinforcing 80 nickel-20 chromium alloy by the addition of such refractory oxides as aluminum oxide, titanium dioxide, zirconium dioxide, chromic oxide and silicon dioxide was made. Powder metallurgical fabrication techniques investigated were pressing and sintering, pressing, sintering and repressing, pressing, sintering followed by hot working, hot pressing and liquid phase sintering. In the "press-sinter" method of fabrication, bars with 1.0% titanium dioxide showed better stress-rupture properties than bars with any of the other oxide additions investigated. Rupture times were 7.45 and 8.7 hours at 1600 F and 7000 psi. Hot forging techniques were found to be applicable for working bars containing oxide additions of 1.0% or less. An 80 nickel-20 chromium alloy reinforced with 1% aluminum oxide and densified by a liquid phase sintering technique resulted in improved stress-rupture properties compared to wrought 80 nickel-20 chromium alloy. This material had a rupture life at 1600 F and 7000 psi in excess of 268 hours; while at 1800 F and 6650 psi, the rupture life was almost 47 hours. The room temperature impact and ultimate tensile strength appeared adequate and the oxidation resistance and thermal shock properties were good. (auth.)—NSA. 13877

6.3.10, 8.9.1

Preliminary Investigation of Guy Alloy as a Turbojet-Engine Bucket Material for Use at 1650 F. R. A. SIGNORELLI, J. R. JOHNSTON AND J. W. WEETON. Lewis Flight Propulsion Lab. National Advisory Cttee. for Aeronautics, Research Memo E56119, Nov. 29, 1956, 22 pp.

Guy alloy, a cast nickel-base material was evaluated as a turbine bucket material for operation at a temperature of 1650 F. As-cast buckets were run in a J33-9 turbojet engine for cycles of 15 minutes at rated speed and five minutes at idle speed. Stress rupture, impact and engine-performance data indicate that Guy alloy may be considered for bucket use at a temperature of 1650 F. Ductility and impact strength of Guy alloy are limited but appear to be adequate for bucket applications. Table compares impact data of Guy, 35-100, Hel1049, 73J, Wrought Inco 550 and heat-treated X-40 alloys. Photomicrographs, graphs, photos.—INCO. 13665

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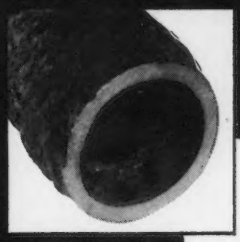

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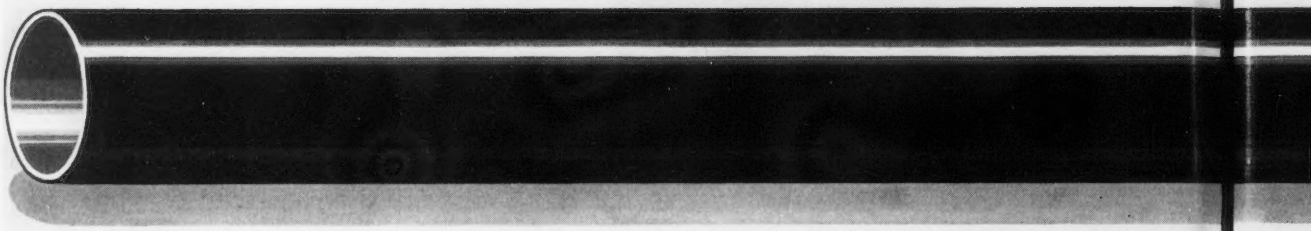

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Outstanding service records tell you that Barrett Enamels offer positively dependable and lasting protection. Easy-flowing coal-tar bases let you apply Barrett Enamels in less time and still be certain of a maximum bond.

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- ☐ **"BARRETT #1300" Enamel** ("Barrett" Millwrap Enamel) – Particularly suited for pipe in distribution systems, gathering and recycling work, mine supply and plumbers' supply, as well as dealers' stock. Supplied in metal drums weighing approximately 600 pounds each.
- ☐ **"BARRETT #1300" Enamel** ("Barrett" AA Enamel)–The all-year enamel! Plasticized enamel for external use only.
- ☐ **"BARRETT #1000" Flux** – Use with narrow-range enamels when atmospheric temperatures are low and the coated pipe is exposed above ground. Used correctly, flux will prevent checking of enamel.
- ☐ **"BARRETT #1660" Coupling Compound** ("Barrett" Waterworks Coupling Compound) – Plasticized material with plenty of flexibility. Withstands movement of pipe at couplings during lowering and after burial – without cracking!
- ☐ **"BARRETT #1700" Enamel** ("Barrett" Hotline Enamel)–A special, fully plasticized enamel having extremely high resistance to high temperatures and soil stress. Has in service temperature range from 0° to 200° F. It will not slide or move off pipe at 200° F., under actual conditions found in underground service. It is an ideal coating where operating temperatures of the lines are high, or for lines in soil exhibiting high soil stress, and in places where there is rough, stony backfill.

Order or specify to the yard-coating applicator the Barrett Pipe Coating Materials that you need to combat corrosion! You can't afford to speculate on protection. Buy Barrett!

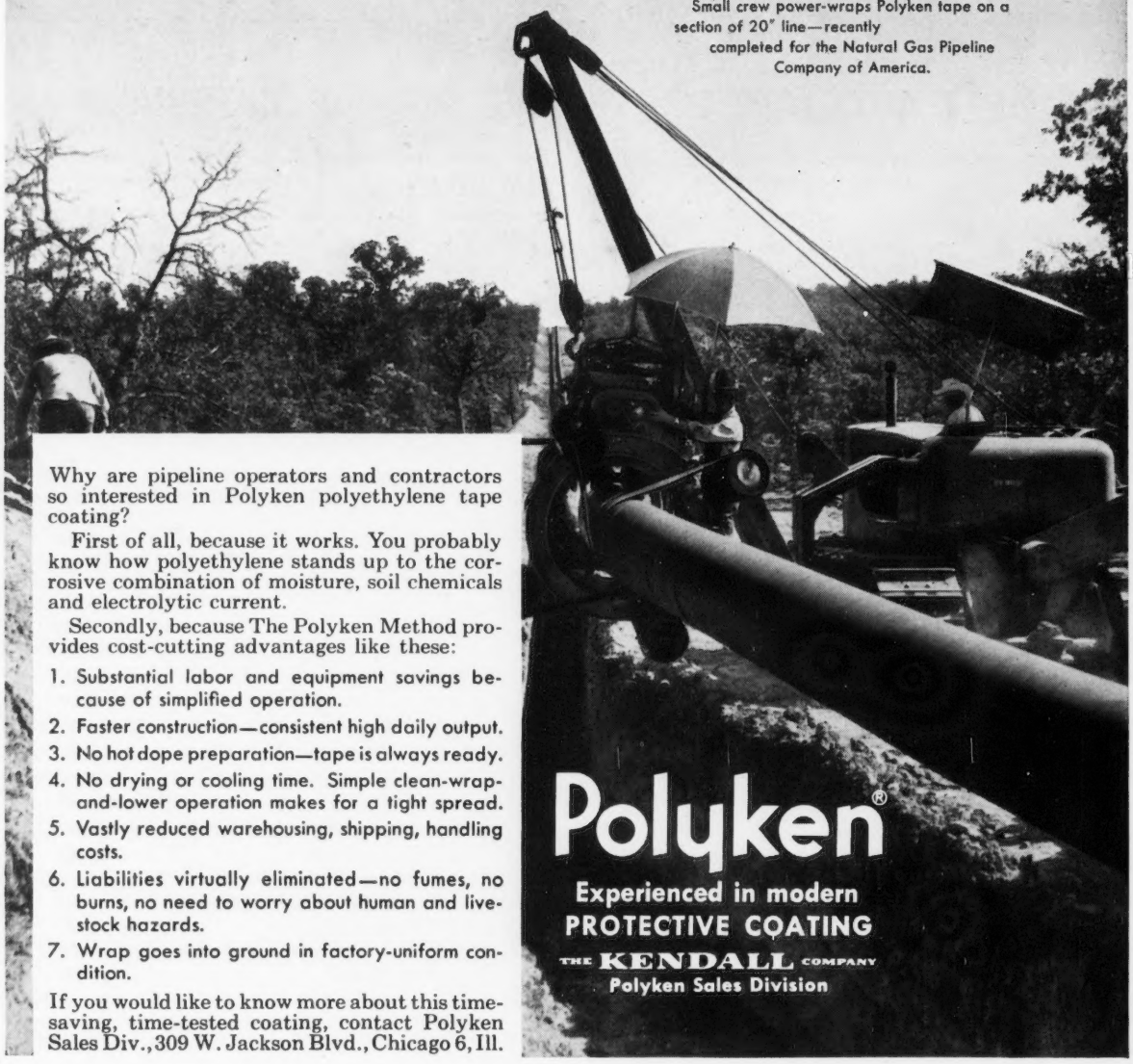
BARRETT PROTECTIVE COATINGS

Barrett Division, Allied Chemical Corporation,
40 Rector Street, New York 6, N. Y.

Allied Chemical

Big-Inch pipeline wrapped the modern way

Polyken Tape saves time, labor and handling costs, yet resists corrosive attack as only polyethylene can



Small crew power-wraps Polyken tape on a section of 20" line—recently completed for the Natural Gas Pipeline Company of America.

Why are pipeline operators and contractors so interested in Polyken polyethylene tape coating?

First of all, because it works. You probably know how polyethylene stands up to the corrosive combination of moisture, soil chemicals and electrolytic current.

Secondly, because The Polyken Method provides cost-cutting advantages like these:

1. Substantial labor and equipment savings because of simplified operation.
2. Faster construction—consistent high daily output.
3. No hot dope preparation—tape is always ready.
4. No drying or cooling time. Simple clean-wrap-and-lower operation makes for a tight spread.
5. Vastly reduced warehousing, shipping, handling costs.
6. Liabilities virtually eliminated—no fumes, no burns, no need to worry about human and livestock hazards.
7. Wrap goes into ground in factory-uniform condition.

If you would like to know more about this time-saving, time-tested coating, contact Polyken Sales Div., 309 W. Jackson Blvd., Chicago 6, Ill.

Polyken®

Experienced in modern PROTECTIVE COATING

THE KENDALL COMPANY
Polyken Sales Division

your Aloyco sales engineer has only one business...

stainless steel valves

Your Aloyco sales engineer is a specialist... he handles only one line. You, as an Aloyco customer, deal directly with a man who knows his product and its application. He is equipped to get close to your problems and you'll find that this closeness to our customers goes right back to the Aloyco Plants. Doesn't it make sense to depend on the man and the company that specialize in corrosion resistant valves exclusively?

ALOYCO 503 Globe Valve... retained bonnet gasket... bolted bonnet... OS&Y... renewable Teflon disc fully retained. The Aloyco Valve line includes a wide range of alloys, types, sizes, and pressures of 150 lb, 300 lb, 600 lb and above. Nuclear Valves up to 2,500 lb.

ALLOY STEEL PRODUCTS COMPANY
Linden, New Jersey

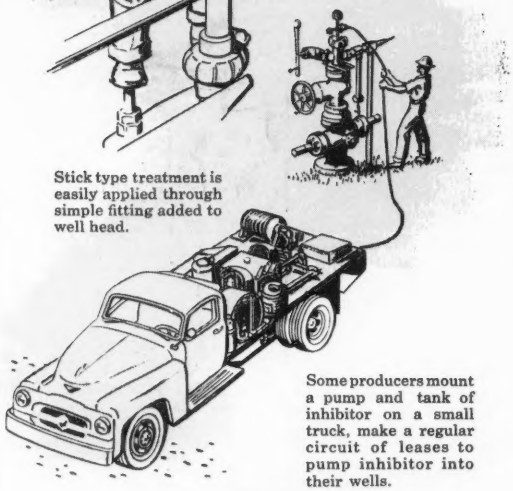
Longer Lasting
ALOYCO VALVES
1ST IN CORROSIVE SERVICE

Facts ON Visco® CORROSION PREVENTION

Here are facts on Visco Corrosion Inhibitor costs in a wide variety of producing oil and gas wells—probably some near you . . . or with corrosion problems like yours. At every well, Visco treatment is only a small fraction of the cost of corrosion damage in untreated wells.

WELL TYPE	WELL LOCATION	DAILY PRODUCTION			Frequency of Visco Treatment	Cost of Visco Treatment per bbl of produced fluid
		Oil bbls	Water bbls	Gas MCF		
Pumping	East Texas	40	300	—	3 times a week	.13¢
Pumping	Eastern Kansas	2	492	—	Once a week	.03¢
Flowing	West Texas	20	6.3	—	Twice a week	.22¢
Pumping	Northern Kansas	10	70	—	Once a day	.62¢
Gas Lift	West Texas	20	20	—	Once a day	2.8¢
Pumping	North Texas	—	2000	—	Once a day	.16¢
Pumping	Eastern Kansas	—	250	—	Twice a week	.11¢
Flowing	East Texas	51	155	1	Once a day	.28¢
Flowing	West Texas	420	—	—	Twice a week	.13¢
Gas	East Texas	25	Trace	22.9	Twice a week	4.6¢*
Pumping	West Texas	420	210	—	Every other day	.14¢
Pumping	West Texas	441	441	—	Every other day	.052¢
Gas	Northern La.	—	—	23.4	Once a day	2.42¢*
Pumping	Eastern Kansas	—	250	—	Once a day	.15¢
Pumping	Kansas	100	948	—	Twice a week	.13¢
Gas	Louisiana	9.2	Trace	300	2 Sticks every other day	.66¢*
Pumping	East Texas	46	176	0.92	Once a day	.27¢
Pumping	East Texas	51	155	1.0	Once a day	.28¢
Pumping	East Texas	20	400	—	Three times a week	.12¢
Pumping	Eastern Kansas	2.5	276	—	Once a week	.09¢

*Cost in cents per million cubic feet.



Stick type treatment is easily applied through simple fitting added to well head.

Some producers mount a pump and tank of inhibitor on a small truck, make a regular circuit of leases to pump inhibitor into their wells.

For fast action on a sound, money-saving approach to your downhole corrosion problems, call Houston, JAckson 8-2495, or contact your Visco Field Service Man.

VISCO PRODUCTS COMPANY
INCORPORATED
1020 Holcombe Blvd. • Houston 25, Texas

Visco . . . CONSISTENTLY EFFICIENT OIL INDUSTRY CHEMICALS

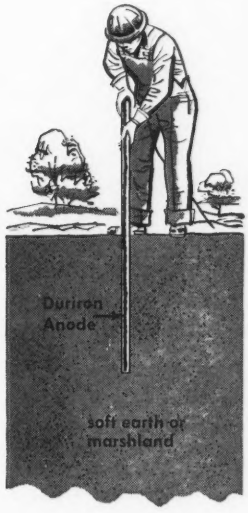
32 DURIRON® ANODES protect 11,000 feet of steel water line without backfill

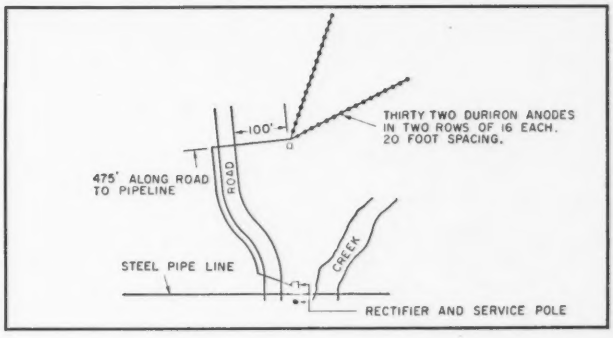
The Problem:

An isolated section of 11,000 feet of steel water line needed cathodic protection. Tests showed current requirements to be 40 amps., but replacement of adjacent wood stave lines called for extra capacity. Ground was a peat bog with water table standing at 6 inches below surface, making backfill methods impossible.

The Installation:

32 Duriron Anodes (2" x 60") were installed without backfill, by digging through the dry surface and then pushing anodes down until the tops were 3 feet below surface. Anodes were installed 20 feet apart, in two rows, with a calculated resistance of one ohm, based on previous experience with similar installations. While conventional backfill columns would have reduced the number of anodes necessary, the use of bare anodes constituted a major saving in cost.




100'
THIRTY TWO DURIRON ANODES IN TWO ROWS OF 16 EACH. 20 FOOT SPACING.
475' ALONG ROAD TO PIPELINE
ROAD
CREEK
STEEL PIPE LINE
RECTIFIER AND SERVICE POLE

The Performance:

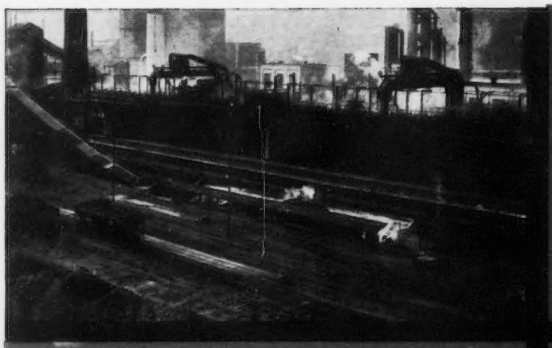
The anode bed is discharging 60 amps. at a terminal voltage of 59 volts. The entire line section is under protection, the minimum potential being 1.18 volts. This affords ample margin to handle prospective additions to the line. Agreement between actual and calculated anode resistance is quite close.

Action:

For further information on this particular installation or for technical assistance on other Duriron impressed current anode installations, write:

DURCO
CORROSION RESISTING ALLOYS & EQUIPMENT

THE DURIRON COMPANY, INC. / DAYTON, OHIO



From the day we produce them . . .

. . . till the day you apply them . . .

PITT CHEM Pipeline Enamels are Backed by a 4-Way Service Program

ON line after line, in all types of terrain and soil, tough, durable *Pitt Chem* Coal Tar Enamels have *proved* their superior ability to provide sure, economical pipeline protection—year after year. But there's *another* big reason why so many companies specify *Pitt Chem* Pipeline Enamels. And that's Pittsburgh's Four-Way service program:

1. Complete Quality Control As a basic producer, Pittsburgh maintains rigid quality control standards at every step of enamel production, from coal to finished coating.

2. Written Specifications Published to guarantee you consistently superior quality and performance from every drum of *Pitt Chem* Pipeline Enamels —in application and in service.

3. Experienced Sales Service *Pitt Chem* sales representatives are experienced coating men. They talk your language, will help you plan the many requirements of your coating job.

4. Technical Service Pittsburgh maintains a full time staff of field service men to work with your field men in the efficient, economical application of coattings. *Write us about your protection requirements!*

★ **PITT CHEM Pipeline Enamels**
★ **PITT CHEM Coal Tar Coatings**
★ **PITT CHEM Insul-Mastic Coatings**

PROTECTIVE COATINGS DIVISION
PITTSBURGH COKE & CHEMICAL CO.
Grant Building • Pittsburgh 19, Pa.

WSW 6956

COAL CHEMICALS • PROTECTIVE COATINGS • PLASTICIZERS • ACTIVATED CARBON • COKE • CEMENT • PIG IRON